Non-Incineration Medical Waste Treatment Technologies

A Resource for Hospital Administrators, Facility Managers, Health Care Professionals, Environmental Advocates, and Community Members

August 2001

Health Care Without Harm
1755 S Street, N.W.
Suite 6B
Washington, DC 20009
Phone: 202.234.0091
www.noharm.org

Non-Incineration Medical Waste Treatment Technologies

A Resource for Hospital Administrators,
Facility Managers, Health Care Professionals,
Environmental Advocates, and Community Members

August 2001

Health Care Without Harm
www.noharm.org

Preface

THE FOUR LAWS OF ECOLOGY . . .

1. Everything is connected to everything else,
2. Everything must go somewhere,
3. Nature knows best,
4. There is no such thing as a free lunch.

Barry Commoner, *The Closing Circle*, 1971

Up to now, there has been no single resource that provided a good frame of reference, objectively portrayed, of non-incineration technologies for the treatment of health care wastes. Vendors of particular technologies have presented self-interested portrayals of their technologies. Other groups such as the World Health Organization (WHO) have presented very generic overviews, usually equating them on par with incinerators. For those health care facilities and communities looking for a tool to really evaluate their options for going beyond incineration for the effective treatment of health care wastes, the search for information has been problematic. It is our hope that this publication will provide a sound tool for all interested parties.

Long before the Health Care Without Harm campaign had a name or members, a number of prescient people – including Barry Commoner, Paul and Ellen Connett, Tom Webster and many others –realized that the growing volume of trash from all economic sectors was a huge problem, and that burning the evidence would not make it go away. Indeed, by the mid-1980's, incineration had already been linked to air emissions of heavy metals and particulates as well as dioxins. They realized that the health care sector presented a uniquely difficult situation because public perception, greatly influenced by images of needles washing up on New Jersey beaches and concerns about HIV and hepatitis, fed the dual notions that "disposable is better" and "burning is better."

Anti-incineration experts like Commoner and the Connetts sought to inform community leaders and regulators in the United States that, as with municipal solid waste, one should systematically view what comes into a health care facility and what leaves it – "everything is connected to everything else" and "everything must go somewhere" – rather than trying to focus only on waste.

Meanwhile, many hospital staff, such as Hollie Shaner, RN of Fletcher-Allen Health Care in Burlington, Vermont, were appalled by the sheer volumes of waste and the lack of reduction and recycling efforts. These individuals became champions within their facilities or systems to change the way that waste was being managed.

In the spring of 1996, more than 600 people – most of them community activists – gathered in Baton Rouge, Louisiana to attend the Third Citizens Conference on Dioxin and Other Hormone-Disrupting Chemicals. The largest workshop at the conference was by far the one devoted to stopping incineration because of concerns about dioxin emissions and other pollutants. A smaller group emerged from that session to focus specifically on medical waste. They were struck by the irony that hospitals entrusted to heal the sick and maintain wellness could be responsible for such a large share of the known dioxin air emissions, for at that time, the United States Environmental Protection Agency (EPA) had listed medical waste incinerators (MWIs) as the number-one identified source.

That summer, the EPA issued its first-ever regulations for medical waste incinerators. These "Maximum Achievable Control Technology" (MACT) rules, issued under the Clean Air Act, sought to control – but not eliminate – the emission of dioxins, furans, mercury, and other pollutants to the environment.

At the September 1996 inaugural meeting of what became the Health Care Without Harm campaign (HCWH), more than 30 people met to discuss the topic of medical waste incineration. Some came from national or grassroots environmental groups or environmental justice organizations; other were involved in health care. One thing that the representatives of the 28 organizations who attended the meeting shared was a desire to stop the incineration of medical waste. While some of the attendees had specific experience with the internal workings of the health care waste management system, many knew very little about what options a hospital might have for dealing with its waste. So the campaign set about the process of getting its questions answered.

In the intervening four years, the members of HCWH have learned a great deal. This knowledge has not been limited to the various technologies. As the campaign has grown from 28 organizations to 330 groups in 33 countries, HCWH members have become aware of unique challenges that some of their colleagues face regarding waste treatment and disposal. For instance, while medical waste incinerators become less common in the United States, the technology is still being exported.

HCWH research has discovered a number of things about the U.S. health care industry that were rather surprising to many in the campaign:

- In 1996, literally hundreds of hospitals had onsite incinerators, which many of them used to burn all of their waste;
- A systematic approach to materials management is lacking for many facilities. Purchasing staff in a health system or hospital do not often interact with their peers in the housekeeping/environmental services department and so are generally not aware of problems that arise from the volume and/or toxicity of the medical supplies they buy for the facility. Likewise, many product-evaluation teams in hospitals do not currently take into account the environmental impact of the products they choose. For example, one-quarter of all disposable plastic medical devices used in the U.S. are now made of polyvinyl chloride (PVC). Scientific research continues to tell the world more about the hazards of PVC, yet staff are often unaware of information about the disposal problems associated with such products;
- Regulators and facility managers alike have not asked what HCWH considers to be basic questions about the emissions of non-incineration technologies, and moreover, emissions testing that does occur does not seem to be modified to reflect changes in waste composition; At an American Society of Healthcare Engineering conference in 1999, one engineer listed the criteria for the "perfect" treatment technology as one that:
    1. does not require a permit;
    2. does not require a public hearing;
    3. can handle all types of waste;
    4. does not break down easily, and if it does need repair, is easy to fix;
    5. requires only one full-time employee (FTE) to operate it, and that employee doesn't require any special training;
    6. does not take up much space in the physical plant;
    7. has no emissions; and, of course,
    8. costs less than what s/he had budgeted for the machine.

Health Care Without Harm has not been able to find such a technology, and it seems likely that this machine does not exist. Indeed, as the campaign has grown and considerable research has been undertaken, HCWH has learned that the vast majority of waste generated in health care is very much like household waste, and therefore can be reduced, reused or recycled instead of treated and landfilled.

As HCWH and this report have evolved, the campaign encountered the perception that if Health Care Without Harm is against incinerators, it must be for landfills. This is not the case. For one thing, this assertion does not address the need for landfilling of incinerator ash residues, which can be of considerable volume and toxicity. Nor does it note that some non-incineration technologies can achieve significant volume reductions. HCWH's goal is to have facilities minimize the amount and toxicity of all waste to the greatest degree possible. If steps are taken to do this, the amount of waste requiring treatment will be considerably less. By reducing the quantity and toxicity of waste, hospitals can not only stop incinerating waste, they can minimize the health and environmental impacts of landfills as well. The campaign realizes that every treatment technology has some environmental impact.

This report seeks to achieve three primary goals:

- to encourage health care staff and the public to view the management of health care-generated waste as a process or system of materials management instead of a single step;
- to supply the reader with information to aid her/him in evaluating non-incineration technologies for regulated medical waste; and
- to raise questions about the public health and environmental impacts of all methods and technologies used to treat regulated medical waste.

What this report will **not** do is specify any one technology for a facility. The tremendous variability in local conditions (including, but not limited to, environmental, economic, regulatory, social and cultural factors) means that different technologies will be appropriate in different parts of the world. Health Care Without Harm does not endorse any technologies or companies, but more importantly, the campaign believes that those decisions must be arrived at by the facility staff and the affected community where the technology will be located.

Jackie Hunt Christensen
Co-coordinator, Health Care Without Harm

CONTRIBUTORS

This resource book is the culmination of efforts by several individuals. The final document was written by:

Jorge Emmanuel, PhD, CHMM, PE

With earlier contributions from:
Charles J. Puccia, PhD
Robert A. Spurgin, MBA

And contributions from the following members of the review committee:

- **Sylvia Altamira**, Health Care Without Harm, Washington, DC
- **Laura Brannen**, Health Care Without Harm, Lyme, NH
- **Janet Brown**, Beth Israel Medical Center, New York, NY
- **Jackie Hunt Christensen**, Institute for Agriculture and Trade Policy, Minneapolis, MN
- **Stephanie C. Davis**, Waste Reduction Remedies SM, Berkeley, CA
- **Tracey Easthope, MPH**, Ecology Center, Ann Arbor, MI
- **Jamie Harvie, PE**, Institute for a Sustainable Future, Duluth, MN
- **Cheryl Holzmeyer**, Washington Toxics Coalition, Seattle, WA
- **Colleen Keegan, RN**, Health Care Without Harm, New York, NY
- **Sanford Lewis, JD**, Strategic Counsel on Corporate Accountability, Waverly, MA
- **Glenn McCrae**, CGH Environmental Strategies, Burlington, VT
- **Peter Orris, MD, MPH**, Great Lakes Center for Occupational and Environmental Safety and Health at the University of Illinois, Chicago, IL
- **Monica Rohde**, Center for Health, Environment and Justice, Falls Church, VA
- **Ted Schettler, MD, MPH**, Science and Environmental Health Network, Boston, MA
- **Neil Tangri**, Multinationals Resource Center, Washington, DC
- **Laurie Valeriano**, Washington Toxics Coalition, Seattle, WA
- **Susan Wilburn, MPH, RN**, American Nurses Association, Washington, DC

ACKNOWLEDGEMENTS

Health Care Without Harm acknowledges financial support from:

- Alida Messinger Charitable Lead Trust
- Angelina Fund
- Anonymous
- Beldon II Fund
- Bydale Foundation
- California Wellness Foundation
- CS Fund
- Goldman Fund
- Homeland Foundation
- Jenifer Altman Foundation
- Jessie B. Cox Charitable Trust
- John Merck Fund
- Joyce Foundation
- Merck Family Fund
- Mitchell Kapor Foundation
- New York Community Trust
- North American Fund for Environmental Cooperation
- Oak Foundation
- One World Foundation
- Rasmussen Foundation
- Rockefeller Family Fund
- StarFire Fund
- Streisand Foundation
- Turner Foundation
- John Merck Foundation
- W. Alton Jones Foundation
- William and Flora Hewlett Foundation, and
- Winslow Foundation

Table of Contents

Executive Summary

Medical waste incinerators emit toxic air pollutants and are a major source of dioxins in the environment. They also generate ash that is potentially hazardous. In 1997, the EPA promulgated regulations for new and existing medical waste incinerators. The EPA requirements in effect increase the cost of incineration. Faced with increasing public opposition to incinerators, many health care facilities are searching for alternatives. This resource book provides information regarding non-incineration treatment technologies.

In order to maximize the benefits of non-incineration technologies, a strategic framework is presented of which the underlying elements are waste minimization and segregation. By implementing a program that includes segregation, source reduction, recycling, and other pollution prevention techniques, one can reduce the amount of infectious waste that needs to be decontaminated. A strategic framework also entails the implementation of an effective waste collection, transport, and storage system; development of waste management and contingency plans; occupational safety and health considerations; and proper siting of the non-incineration technology.

Analysis of the medical waste stream is an important first step in selecting a non-incineration technology. Hospitals generate between 8 to 45 pounds of waste per bed per day in the form of general trash, infectious (red bag) waste, hazardous waste, and low-level radioactive waste. Infectious waste is estimated to be about 15% or less of the overall waste. The following categories are commonly used in describing the components of infectious waste: cultures and stocks, pathological wastes, blood and blood products, sharps, animal wastes, and isolation wastes. A medical waste audit is a useful tool to find out the sources of waste in a health care facility, their compositions, and rates of generation. An audit may also provide information on waste minimization and handling practices, segregation efficiency, "overclassification," regulatory compliance, and costs. After an analysis of the hospital's waste is completed, the facility is in a better position to determine what kind and what size of non-incineration treatment technology would best meet their needs.

Four basic processes are used in medical waste treatment: thermal, chemical, irradiative, and biological. Thermal processes rely on heat to destroy pathogens (disease-causing microorganisms). They can be further classified as low-heat thermal processes (operating below 350°F or 177°C), medium-heat thermal processes (between 350 to about 700°F), and high-heat thermal processes (operating from around 1000°F to over 15,000°F). The low-heat processes utilize moist heat (usually steam) or dry heat. High-heat processes involve major chemical and physical changes that result in the total destruction of the waste. Chemical processes employ disinfectants to destroy pathogens or chemicals to react with the waste. Irradiation involves ionizing radiation to destroy microorganisms while biological processes use enzymes to decompose organic matter. Mechanical processes, such as shredders, mixing arms, or compactors, are added as supplementary processes to render the waste unrecognizable, improve heat or mass transfer, or reduce the volume of treated waste.

For each of these processes, an overview and principles of operation are presented along with information on the types of waste treated, emissions and waste residues, microbial inactivation efficacy, advantages, disadvantages, and other issues. Specific examples of technologies are provided. Technology descriptions are based on vendor data, independent evaluations, and other non-proprietary sources where available. Many technologies are fully commercialized, while others are still under development or newly commercialized. Since technologies change quickly in a dynamic market, facilities should contact vendors to get the latest and most accurate data on the technologies when conducting their technical and economic evaluation of any technology. ***Health Care Without Harm does not endorse any technology, company, or brand name, and does not claim to present a comprehensive list of technologies.***

Steam disinfection, a standard process in hospitals, is done in autoclaves and retorts. The following steam treatment systems are described as examples: Bondtech, ETC, Mark-Costello, Sierra Industries, SteriTech, and Tuttnauer. More recent designs have incorporated vacuuming, continuous feeding, shredding, mixing, fragmenting, drying, chemical treatment, and/or compaction to modify the basic autoclave system. Examples of these so-called advanced autoclaves are: San-I-Pak, Tempico Rotoclave, STI

Chem-Clav, Antaeus SSM, Ecolotec, Hydroclave, Aegis Bio-Systems, and LogMed. Microwave technology is essentially a steam-based low-heat thermal process since disinfection occurs through the action of moist heat and steam. Sanitec and Sintion are examples of large and small microwave units, respectively. Dry-heat processes do not use of water or steam. Some heat the waste by forced convection, circulating heated air around the waste or using radiant heaters. KC MediWaste and TWT Demolizer are examples of large and small dry-heat systems, respectively. EWI and CWT depolymerize the waste and are examples of medium-heat thermal processes.

High-heat thermal processes operate at or above the temperatures achieved in incineration. As such, they can handle the full range of medical waste. In most of these technologies, pyrolysis (not combustion or burning) is the dominant process. Pyrolysis involves a set of chemical reactions different from incineration and hence, different gaseous products and waste residues are produced. In many cases, pollutant emissions from pyrolysis units are at levels lower than those from incinerators. Waste residues may be in the form of a glassy aggregate, recoverable metals, or carbon black. The high heat needed for pyrolysis can be provided by resistance heating (Bio-Oxidation), plasma energy (e.g., Anara, Daystar, EPI/Svedala, HI Disposal PBPV, MSE, Plasma Pyrolysis Systems, Startech, Unitel, Vance IDS, and VRI), induction heating (Vanish), natural gas (Balboa Pacific), or a combination of plasma, resistance heating, and superheated steam (IET). Superheated steam reforming (Duratek) is another high-heat thermal process. An advanced burn technology (NCE TurboClean) is included because of its unique features and low emissions. Pyrolysis systems are a relatively new technology and require careful evaluation.

Chemical technologies use disinfecting agents in a process that integrates internal shredding or mixing to ensure sufficient exposure to the chemical. Until recently, chlorine-based technologies (sodium hypochlorite and chloride dioxide) were the most commonly used; examples include Circle Medical Products, MedWaste Technologies Corporation, and Encore. Some controversy exists regarding possible long-term environmental effects especially of hypochlorite and its byproducts in wastewater. Non-chlorine technologies are quite varied in the way they operate and the chemical agents employed. Some use peroxyacetic acid (Steris EcoCycle 10), ozone gas (Lynntech), lime-based dry powder (MMT, Premier Medical Technology), acid and metal catalysts (Delphi MEDETOX and CerOx), or biodegradable proprietary disinfectants (MCM). The alkaline hydrolysis technology (WR2) is designed for tissue and animal wastes as well as fixatives, cytotoxic agents, and other specific chemicals. Safety and occupational exposures should be monitored when using any chemical technology.

Electron beam technology bombards medical waste with ionizing radiation, causing damage to the cells of microorganisms. Examples of e-beam technologies designed for medical waste treatment include BioSterile Technology, Biosiris and the University of Miami's Laboratories for Pollution Control Technologies. Unlike cobalt-60 irradiation, electron beam technology does not have residual radiation after the beam is turned off. However, shields and safety interlocks are necessary to prevent worker exposure to the ionizing radiation.

Biological processes, such as the Bio-Converter, use enzymes to decompose organic waste. Several examples of small-scale sharps treatment technologies are also presented in this resource book.

Health care facilities should consider the following factors when selecting an non-incineration technology: throughput capacity, types of waste treated, microbial inactivation efficacy, environmental emissions and waste residues, regulatory acceptance, space requirements, utility and other installation requirements, waste reduction, occupational safety and health, noise, odor, automation, reliability, level of commercialization, background of the technology manufacturer or vendor, cost, and community and staff acceptance. Some common techniques for comparing costs of non-incineration technologies include annual cash flow projections, net present value, and life-cycle cost methods. Where available, capital cost estimates of non-incineration technologies are provided along with other comparative data. Various general approaches to acquiring a technology, including financing options, are also presented.

No one technology offers a panacea to the problem of medical waste disposal. Each technology has its advantages and disadvantages. Facilities have to determine which non-incineration technology best meets their needs while minimizing the impact on the environment, enhancing occupational safety, and demonstrating a commitment to public health. This resource book provides general information to assist hospital administrators, facility managers, health care professionals, environmental advocates, and community members towards achieving those goals.

Chapter 1

Introduction: Why Non-incineration Technologies

"INCINERATOR PLAN PROVOKES COMPLAINTS" is not a headline any medical facility manager wants to see, but this is precisely what happened to one hospital in 1995. After spending $14 million on a modern facility, the hospital faced strong opposition to the incinerator. The reaction to the new facility was a consequence of a growing public awareness of environmental and other problems associated with medical waste incinerators.

Decision-makers faced with the choice of upgrading or maintaining an existing medical waste incinerator, installing a new one, or contracting with a hauler who may take the waste to a large off-site incinerator should consider the following:

INCINERATORS EMIT TOXIC AIR POLLUTANTS

A medical waste incinerator releases into the air a wide variety of pollutants including dioxins and furans, metals (such as lead, mercury, and cadmium), particulate matter, acid gases (hydrogen chloride and sulfur dioxide), carbon monoxide, and nitrogen oxides. These emissions have serious adverse consequences on worker safety, public health and the environment. Dioxins, for example, have been linked to cancer, immune system disorders, diabetes, birth defects, and other health effects. Medical waste incinerators are a leading source of dioxins and mercury in the environment. It must be noted, however, that non-incineration technologies can also have toxic emissions (although research indicates that these occur in smaller amounts).

INCINERATOR ASH IS POTENTIALLY HAZARDOUS

Ash remaining at the bottom of an incinerator after burndown often contains heavy metals that may leach out. Dioxins and furans may also be found in the bottom ash. In states where low-level radioactive waste is incinerated, the ash residue may also contain traces of radioactive isotopes. If test results of the ash exceed the limits under EPA's toxicity characteristic leachate procedure (TCLP), the ash must be treated as hazardous waste. TCLP is a testing procedure wherein an extract from a 100 gram sample of the ash is tested for 40 toxic substances; if the analysis shows that one of the substances is present at a concentration higher than that specified in the regulation, the ash is considered hazardous waste.

Disposal of hazardous waste is subject to regulations under the Resource Conservation and Recovery Act (RCRA). Note, however, that the TCLP tests for only a limited number of toxic substances and is conducted on a very small sample that may not be representative of the entire batch of bottom ash. TCLP uses an extraction procedure that does not reproduce long-term natural leaching as occurs in landfills. Moreover, not every batch of ash is tested. Due to the diverse materials that comprise medical waste, the resulting ash composition will vary considerably and yet some facilities test the ash only once a year or only one time.

Fly ash (ash that is carried by the air and exhaust gases up the incinerator stack) contains heavy metals, dioxins, furans, and other toxic chemicals that condense on the surface of the ash. Even when the fly ash is removed from the exhaust stream by pollution control devices such as baghouse filters, the toxic materials remain concentrated on the filter cake and should be treated as hazardous waste.

INCINERATORS MUST MEET "NEW" REGULATORY REQUIREMENTS

New and existing medical waste incinerators must comply with the 1997 EPA regulation that sets limits on their air emissions. To meet the requirements, incinerators will need air pollution control devices such as scrubbers. In older incinerators, secondary chambers may have to be retrofitted. Periodic stack tests must be performed to show compliance with the rules, and facilities must continuously monitor operating parameters such as secondary chamber temperature. The regulations also require operator training and qualification, inspection, waste management plans, reporting, and recordkeeping.

Before 1997, there were no federal regulations governing air emissions from medical waste incinerators. Under the regulation, operators of medical waste incinerators must meet the emission limits within a year after the EPA approval of their state's implementation plan or, if their states do not have their own control plans, in keeping with the federal implementation plan promulgated in August 2000. Regardless of which plan applies to a specific incinerator, all existing medical waste incinera-

tors must be in full compliance by September 2002. (More information about the "hospital/medical/infectious waste incinerator rule" can be found in http://www.epa.gov/ttnuatw1/129/hmiwi/rihmiwi.html; see also Chapter 10.)

INCINERATORS MAY NOT BE COST-EFFECTIVE

Cost is another key factor in the consideration of medical waste disposal. In evaluating the costs of incineration, decision-makers should take into account, among others, capital and operating costs of the incinerator plus scrubber and other pollution control devices; the cost of secondary chamber retrofits for old incinerators; the costs of periodic stack testing, continuous monitoring, operator training and qualification; and the costs of maintenance and repair especially in relation to refractory wear or failure. The hospital mentioned earlier estimated that installing the necessary pollution control devices on their incinerator to meet the EPA rule would add $650,000 more in costs than a recycling option.

MANY COMMUNITIES OPPOSE INCINERATION

A plume of smoke from a hospital incinerator stack stands as a frequent reminder of that facility's environmental impact on the surrounding community. The public's concern for a clean environment and increasing community opposition to incineration should be paramount factors in deciding whether or not to install or continue operating a medical waste incinerator. Choosing a cleaner non-incineration technology demonstrates the health care organization's commitment to protecting public health and the environment.

No technology offers a panacea to the problem of medical waste disposal. In general, however, non-incineration technologies appear to emit fewer pollutants. Most non-incineration technologies generate solid residues that are not hazardous. Alternative technologies (in particular, non-burn technologies) are not subject to EPA's medical waste incinerator regulations. Many hospitals have also concluded that upgrading or purchasing an incinerator is not as cost-effective as implementing a waste minimization program and installing a non-incineration technology. Subsequent chapters examine the advantages and disadvantages of non-incineration technologies in detail.

Chapter 2

Strategic Framework for Non-incineration Technologies: The Broader Context

Before dealing with the technical and economic issues relating to non-incineration technologies (Chapters 4 to 11), it is crucial to situate the use of non-incineration technologies in a broader context. The decision to select an alternative technology must encompass a strategic framework dealing with various aspects of medical waste management. Doing so ensures that the maximum environmental, occupational safety, and economic benefits of non-incineration technologies can be achieved.

In the past, many hospitals simply dumped all their waste streams together—from reception area trash, cardboard boxes, and kitchen waste to operating room wastes, contaminated sharps, and lab waste—and burned them in their incinerators. There were no incentives to separate, recycle, or reduce waste. A commitment to public health and environmental protection, regulatory compliance, and the need to reduce costs require a new framework for dealing with hospital waste.

The underlying elements of a strategic framework are **waste minimization** and **segregation**. Different components of the waste stream must be kept separate from each other. Specifically, potentially infectious waste, regular trash, hazardous waste, and low-level radioactive waste must be segregated from each other. Every effort must be made to minimize each of these waste streams and each must be disposed of properly. The infectious waste that remains can then be treated using an alternative (non-incineration) technology. (Note: Some facilities incinerate waste that had already been treated by a non-incineration technology, thereby defeating the purpose of using an alternative.)

Other elements of a strategic framework include: developing a safe and effective collection, transport, and storage system; waste management and contingency planning; protecting the health and safety of workers; and proper siting of the non-incineration technology. This chapter describes each of these elements. In addition, understanding the waste stream is a necessary step. Chapter 3 discusses what comprises medical waste and what is involved in a waste analysis.

WASTE MINIMIZATION IS KEY

Waste minimization is the reduction, to the greatest extent possible, of waste that is destined for ultimate disposal, by means of reuse, recycling, and other programs. The potential benefits of waste minimization are: environmental protection, enhanced occupational safety and health, cost reductions, reduced liability, regulatory compliance, and improved community relations. The following is the recommended hierarchy of waste minimization techniques in order of decreasing preference:

1. **Segregation** – making sure waste items are in the appropriate container. Staff training is essential to keep regulated medical waste, hazardous waste such as mercury, low-level radioactive waste, and regular trash separated from each other.
2. **Source reduction** - minimizing or eliminating the generation of waste at the source itself; source reduction should have a higher priority than recycling or reuse. Users, waste managers, and product standardization committees should be aware of what waste is generated by the products they buy. Source reduction requires the involvement of purchasing staff. Steps should be taken to reduce at the source regulated medical waste, hazardous waste, low-level radioactive waste, as well as regular trash. Some specific source reduction techniques include:
   a. **Material elimination, change or product substitution**, e.g., substituting a non-toxic biodegradable cleaner for a cleaner that generates hazardous waste under RCRA; employing multiple-use instead of single-use products; using short-lived radionuclides instead of radium-226 needles in cancer treatment
   b. **Technology or process change,** e.g., using non-mercury-containing devices instead of mercury thermometers or mercury switches; using ultrasonic or steam cleaning instead of chemical-based cleaners
   c. **Good operating practice**, e.g., improving inventory control; covering disinfecting solution trays to prevent evaporative losses; using the minimum formulation recommended for an application

d. **Preferential purchasing** such as selecting vendors with reduced packaging

3. **Resource recovery and recycling** - recovery and reuse of materials from the waste stream. Some specific examples include:
   a. Recycling newspapers, packaging material, office paper, glass, aluminum cans, construction debris, and other recyclables
   b. Purchasing products made of post-consumer recycled material
   c. Composting organic food waste
   d. Recovering silver from photographic chemicals
4. **Treatment** - treatment to remove and concentrate waste, preferably in process rather than end-of-pipe treatment. An example might be the use of filters and traps to remove mercury from wastewater. In the case of infectious waste, treatment entails the destruction of pathogens. This is where non-incineration technologies come in.
5. **Proper Disposal** – when all possible waste minimization options have been exhausted, the remaining waste should be disposed in the method with the least environmental impact. With most non-incineration technologies, the treated waste can be disposed in a regular municipal waste landfill. Health Care Without Harm does not support the incineration of medical waste as a means of treatment or *after* disinfection.

The development of a waste minimization program involves planning and organization, assessment, feasibility analysis, implementation, mandatory training, and periodic evaluation. The commitment of top management is essential. The active involvement of individuals from different departments, communication, and educational programs are necessary for successful implementation.

Waste reduction efforts received attention and support on the national level in 1997 when a Memorandum of Understanding (MOU) between the American Hospital Association (AHA) and the Environmental Protection Agency (EPA) was signed. This MOU included a commitment to reduce total waste by one-third by the year 2005 and by 50 percent by 2010; to virtually eliminate mercury-containing waste by 2005; and to minimize the production of persistent, bioaccumulative, and toxic ("PBT") pollutants. (For more information, see http://www.ashes.org/services or http://www.epa.gov/glnpo/toxteam/ahamou.htm.)

Many resources are available to assist health care organizations develop an effective waste minimization program in their facilities (see box insert, next page). Many associations and states have developed guides to assist hospitals in waste reduction and pollution prevention. Readers should contact their state hospital association and state environmental agency (especially the department dealing with pollution prevention) to find out what is available. Books such as *Guidebook for Hospital Waste Reduction Planning and Program Implementation, An Ounce of Prevention: Waste Reduction Strategies for Health Care Facilities,* and *The Waste Not Book* provide valuable information and practical suggestions.

WHY SEGREGATION IS ESSENTIAL

Chapter 3 describes the different waste streams in a hospital. **Commingling** (mixing different waste streams) inflates the amount of waste that requires special treatment hence increasing the cost of treatment and disposal. If infectious ("biohazardous") and hazardous wastes are blended together, the mixture must be treated as *both* hazardous and biohazardous. Most haulers are permitted to haul only one or the other. For example, haulers permitted to haul hazardous waste will not accept mixed hazardous and infectious waste; the entire mixture will have to be rendered non-infectious first and then hauled as hazardous waste. If regular trash is added to "red bag" waste, the combined quantity must be treated as infectious waste. "Red-bag" waste is about five times more expensive to treat than non-regulated medical waste. Commingling simply does not make sense.

Segregation means separating different types of waste at the point of generation and keeping them isolated from each other. By segregating waste, appropriate resource recovery and recycling techniques can be applied to each separate waste stream. Moreover, the amount of infectious waste that needs to be disinfected under state regulations, the quantities of hazardous waste to be treated under the Resource Conservation and Recovery Act, and the low-level radioactive waste that falls under U.S. Nuclear Regulatory Commission and state regulations are minimized.

Another crucial reason for segregation has to do with the consequences of introducing hazardous or radioactive substances into treatment systems for infectious waste. Let us consider what happens to a chemical when it enters a treatment process, including incineration. There are three possibilities:

1. **The chemical exits the treatment chamber unchanged and goes out with the treated waste.** EXAMPLE: Cytotoxic (chemotherapy) or radioac-

RECOMMENDED READINGS ON WASTE MINIMIZATION

Waste minimization model plans and guides including a chemical waste minimization plan, mercury-virtual elimination plan, and guide to environmentally preferable purchasing: Hospitals for a Healthy Environment (an American Hospital Association and U.S. Environmental Protection Agency partnership). (available at www.h2e-online.org)

On-line resources on waste minimization for hospitals and laboratories, Minnesota Technical Assistance Program (MnTAP), University of Minnesota, School of Public Health, Division of Environmental and Occupational Health. (www.mntap.umn.edu)

Waste Minimization in the Healthcare Industry: A Resource Guide, J. Emmanuel, EPRI, Palo Alto, CA: 1999. TR-113841. (EPRI, 3412 Hillview Avenue, Palo Alto, CA 94303; 800-313-3774)

Environmental Management in Healthcare Facilities, Edited by K. D. Wagner, C.D. Rounds, and R. Spurgin, W.B. Saunders Company, Philadelphia, Pennsylvania, 1998. (W.B. Saunders Company, The Curtis Center, Independence Square West, Philadelphia, PA 19106; 800-545-2522; http://www.harcourthealth.com/)

Guidebook for Hospital Waste Reduction Planning and Program Implementation, Glenn McRae and Hollie Gusky Shaner, RN, American Society for Healthcare Environmental Services (American Hospital Association), Chicago, Illinois, 1996. (AHA Services, Inc., P.O. Box 92683, Chicago, IL 60675-2683; 800-AHA-2626)

An Ounce of Prevention: Waste Reduction Strategies for Health Care Facilities, C.L. Bisson, G. McRae, and H.G. Shaner, American Society for Healthcare Environmental Services (American Hospital Association), Chicago, Illinois, 1993. (AHA Services, Inc., P.O. Box 92683, Chicago, IL 60675-2683; 800-AHA-2626)

The Waste Not Book, Public Affairs Division, Minnesota Hospital Association, Minneapolis, Minnesota, 1993. (Minnesota Hospital and Healthcare Partnership, 2550 W. University Avenue, Suite 350-S, St. Paul, MN 55114-1900; 800-462-5393; www.mhhp.com)

Facility Pollution Prevention Guide, EPA/600/R-92/088, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio, 1992. *

Hospital Pollution Prevention Study, EPA/600/2-91/024, prepared by R. Linett for Department of Veterans Affairs, Washington, DC, and Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, Ohio, July 1991. *

Guides to Pollution Prevention: Selected Hospital Waste Streams (formerly titled "Guide to Waste Minimization in Selected Hospital Waste Streams"), EPA/625/7-90/009, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, Ohio, June 1990. *

Waste Minimization Opportunity Assessment Manual, EPA/625/7-88-003, U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, 1988. *

ON MERCURY WASTE:

"Mercury and the Healthcare Professional," video (15 min), Minnesota Office of Environmental Assistance, St. Paul, MN, 1997. (Minnesota Office of Environmental Assistance, 520 Lafayette Road N, Floor 2, St. Paul, MN 55155-4100; 800-657-3843; http://www.moea.state.mn.us)

The Case Against Mercury: Rx for Pollution Prevention, Terrene Institute, Washington, DC, 1995. (Terrene Institute, 4 Herbert Street, Alexandria, VA 22305; 703-548-5473; http://www.terrene.org)

Protecting by Degrees: What Hospitals Can Do To Reduce Mercury Pollution, Environmental Working Group/The Tides Center, Washington, DC, May 1999. (Health Care Without Harm, c/o Center for Health, Environment, and Justice, P.O. Box 6806, Falls Church, VA 22040; 703-237-2249; www.noharm.org)

Becoming a Mercury Free Facility: A Priority to be Achieved by the Year 2000, H.G. Shaner, Professional Development Series (Catalog No. 197103), American Society for Healthcare Environmental Services (American Hospital Association), Chicago, Illinois, November 1997. (AHA Services, Inc., P.O. Box 92683, Chicago, IL 60675-2683; 800-AHA-2626)

Mercury Pollution Prevention in Healthcare: A Prescription for Success, National Wildlife Federation, Ann Arbor, Michigan, July 1997. (NWF Great Lakes Natural Resource Center, 506 E. Liberty, 2nd Floor, Ann Arbor, MI 48104-2210; 800-822-9919; www.nwf.org/greatlakes; publication is found in http://www.nwf.org/greatlakes/resources/mercury.html)

* Contact EPA Publications at 800-490-9198 or check out http://www.epa.gov/epahome/publications.htm for EPA reports.

tive wastes passing through an electron beam system would remain unchanged and contaminate the landfill in which the treated waste is eventually disposed.

2. **The chemical undergoes a physical change and exits the treatment chamber in one or more forms.** EXAMPLE: Spent methanol or formaldehyde solutions placed in a microwave unit or high velocity-heated air processor would partially or completely vaporize, releasing toxic gases into the air. Mercury introduced into an autoclave would volatilize. Some of the mercury would remain as a liquid and leave with the treated waste to eventually contaminate the landfill; some of the mercury may exit with the steam condensate to contaminate wastewater, and another portion would escape as mercury vapor in air as the chamber door is opened.
3. **The chemical undergoes a chemical transformation in the treatment process and the reaction byproducts exit along with the treated waste.** EXAMPLE: This is what happens in an incinerator. There is strong evidence that chlorinated plastics, such as polyvinyl chloride (PVC), burnt in an incinerator produce intermediate chemicals that react to form dioxins and furans, which escape the incinerator stack through the fly ash.

The chemical may also accumulate in the treatment chamber but could eventually exit, thereby contaminating other waste loads. In any case, as the material and byproducts are toxic, they could end up poisoning the environment and result in future exposures to human populations. Hence, by not segregating waste, one nullifies the environmental benefits of non-incineration technologies and, in some cases, may violate the law.

Techniques for Segregation

Segregation entails separating certain types of waste into appropriate containers at the point of generation. Infectious waste should be segregated in clearly marked containers that are appropriate for the type and weight of the waste. Except for sharps and fluids, infectious wastes are generally put in plastic bags, plastic-lined cardboard boxes, or other leak-proof containers that meet specific performance standards. In the United States, red or orange bags are commonly used to designate infectious waste, while general waste is placed in black, white, or clear bags. In other countries, yellow, brown, and black bags are used for infectious, chemical/pharmaceutical, and general wastes, respectively. Labels affixed to infectious waste containers should include the international biohazard symbol in a contrasting color. The primary containers used for sharps disposal must be rigid, leak-proof, break-resistant, and puncture-resistant. If the primary container could leak during transport, a secondary leak-proof container should be added.

To improve segregation efficiency and minimize incorrect use of containers, the proper placement and labeling of containers must be carefully determined. General trash containers placed beside infectious waste containers could result in better segregation. Too many infectious waste containers tend to inflate waste volume but too few containers may lead to noncompliance. Minimizing or eliminating the number of infectious waste containers in patient care areas (except for sharps containers which should be readily accessible) may further reduce waste. Facilities should develop a segregation plan that includes staff training.

COLLECTION, TRANSPORT, AND STORAGE

Medical waste collection practices should be designed to achieve an efficient movement of waste from points of generation to storage or treatment while minimizing the risk to personnel. Generally, carts are used to transport waste within a facility. Carts used for infectious waste should not be used for other purposes. They should be kept shut during transport to prevent spillage and avoid offensive sights and odors. A program of regular cleaning and disinfection of carts should be in place.

Containment, labeling, and storage specifications for medical waste containers should comply with applicable regulations such as OSHA's Bloodborne Pathogen rule. If infectious waste has to be stored, the storage site should have good drainage, easy-to-clean surfaces, good lighting, ventilation, and should be safe from weather, animals, and unauthorized entry. To prevent putrefaction, the following *maximum* storage times are suggested by the World Health Organization: 72 hours in winter and 48 hours in summer for temperate climates; 48 hours in the cool season and 24 hours in the hot season for warm climates.[1] Some states require refrigeration of regulated medical waste if storage times exceed a specified time limit. An on-site non-incineration technology may eliminate the need for storage beyond the time limits.

WASTE MANAGEMENT AND CONTINGENCY PLANS

A **medical waste management plan** is documentation describing the facility's program for managing waste from generation to disposal. The plan should address the following issues: (1) compliance with regulations; (2) responsibilities of staff members; (3) definitions/classification of medical waste; (4) procedures for handling medical waste; and (5) training plans. The procedures should cover: identification, segregation, containment, labeling, storage, treatment, transport, disposal, monitor-

ing, record keeping, and contingency planning. Protecting the health and safety of the staff, patients, and visitors; protecting the environment; and complying with applicable regulations are some of the overall goals of a waste management plan. The plan should be reviewed periodically, and all staff members involved in medical waste should read it. The waste management plan can be linked to the facility's waste minimization plan, a chemical safety plan, a hazard communication plan, and an exposure control plan as required by OSHA.

Health care facilities should be prepared to respond to contingencies such as spills, exposures to infectious waste, or failure of waste treatment systems. Most spills in a health care facility can be cleaned up using spill containment and cleanup kits. Procedures should also be developed in response to exposure incidents. Follow-up procedures after an exposure are required under OSHA's Bloodborne Pathogen Standard. In anticipation of equipment downtime due to repair and maintenance, alternate plans should be made to store medical waste or transport it for treatment at an off-site facility using a non-incineration technology.

OCCUPATIONAL SAFETY AND HEALTH

Considerations of occupational safety and health should always be part of a framework for medical waste management. There are many potential hazards when dealing with medical waste. Some hazards are associated with handling and transport such as:

- needle-sticks
- injuries due to other sharps, such as broken glass
- ergonomic issues especially related to lifting
- blood splatter during waste handling
- aerosolized pathogens (disease-causing microorganisms released as aerosols or tiny droplets suspended in air) during loading, compaction, or break up of untreated waste
- spills
- chemical and hazardous drug exposure.

Other hazards depend on which treatment technology is used:

- hot surfaces that cause burns
- steam from a treatment chamber
- elevated temperatures in the work area due to insufficient cooling and ventilation
- volatile organic compounds and other chemicals released into the workplace
- toxic pollutants from a short exhaust stack
- ionizing radiation from irradiative processes
- non-ionizing radiation such as from microwaves
- noxious odors
- noise pollution.

The National Institute of Occupational Safety and Health (NIOSH) funded a two-year study on chemical, biological, and safety hazards associated with non-incineration technologies. The study looked at steam autoclave, microwave, chemical-mechanical, and pyrolysis systems. In general, they found that no volatile organic compounds exceeded existing OSHA permissible exposure limits. All metal samples in the air were minimal, mostly below detection limits. With regards to biological hazards, they found the greatest hazard and potential health risk from blood splatter, as workers emptied waste containers into the treatment system. The next major concern was ergonomics, as the technologies required extensive manual handling of heavy waste containers. Finally, there were general safety issues, such as the need to use personal protective equipment.

Health care facilities should identify all possible occupational hazards in the handling, treatment, and disposal of medical waste. A team—involving environmental services staff and workers who will be using the equipment as well as a trained industrial hygienist or safety officer, infection control nurse, occupational health staff, facility engineer, and other professionals—can work together to identify hazards and identify ways to reduce or eliminate them. Minimizing these hazards may entail: warning systems, engineering controls such as safer needle devices, safe work practices, use of personal protective equipment, and administrative controls. Proper protective clothing and gear must be provided; ill-fitting protective equipment that hinders worker movement or performance increases the likelihood that they will not be used. Preventive measures such as staff immunization for tetanus and Hepatitis B virus are also important. In addition, medical monitoring, periodic evaluation of safety measures, and documentation are part of an occupational safety and health program pertaining to medical waste management. Last, but not least, worker training is critical.

SITING AND INSTALLATION

For the larger technologies, facilities may need to build a new structure to house the technology or renovate existing space, such as the vacated area after the demolition and removal of an old incinerator. Each technology will have different requirements for space, foundation, utility

service connections, ventilation, and support equipment. In determining the best location for a non-incineration technology, one must take into account safe transfer routes, average distances from waste sources, temporary storage requirements, as well as space allowances needed by workers to maneuver safely around the treatment unit. The location of the technology should not cause traffic problems as waste is brought in and out. Odor, noise, the visual impact of medical waste operations on patients and visitors, public access, and security should also be considered.

Exhaust vents, if any, from the treatment technology should not be located near inlets to HVAC systems. If the technology involves heat dissipation, there must be sufficient cooling and ventilation. Electrical systems, including wiring and grounding, should be designed so as to prevent conducted and radiated emissions that may interfere with sensitive electronic equipment in the hospital. Conversely, treatment technologies that use computer controllers have to be protected from power disturbances that may affect their operations.

Ergonomic-related issues are also important. Such issues include the height of the feed section after installation, the height of conveyor assemblies, how easily red bags or boxes can be transferred from carts to equipment hoppers, the location of equipment controls, the use of ramps or stairs, etc.

Traditionally, siting and installation have been the purview of engineers dealing with the foundation, electrical connections, sewer, HVAC (heating, ventilation, and air conditioning), utilities, etc. By taking a team approach and involving facility engineering, environmental services, housekeeping, safety or industrial hygiene, infection control, and occupational health, important aspects such as occupational health and safety become part of decisions relative to siting and installation.

On-Site versus Off-Site Treatment

Other than on-site incineration, health care facilities have two other options: treatment using an on-site non-incineration technology, or hauling and off-site treatment. HCWH recognizes that on-site treatment is not always an option for some health care facilities.

Waste management firms and waste brokers offer health care organizations transport, storage, treatment, and disposal services. Many hospitals cite lower costs as a major advantage of hauling. However, to establish the full costs of hauling, it is important to take hidden costs into account (see Chapter 11). One of the biggest disadvantages of hauling is potential liability associated with improper disposal by the hauler, occupational injuries during transfer of the waste, and roadway accidents that may result in spills or injuries. Another disadvantage is the need to comply with yet another set of federal, state, and local regulations for inter- and intra-state transport of regulated medical waste. *Regardless of disclaimers, waste generators ultimately bear responsibility for what happens to their waste.*

From an environmental and public health standpoint, a serious disadvantage of hauling and off-site treatment is the possibility that the waste is being treated in a large regional incinerator, thereby contributing to the release of toxic pollutants. On the other hand, the waste might be treated with a large-scale non-incineration technology with fewer emissions to the environment. In any case, it is the responsibility of the health care organization to determine how their waste is ultimately destroyed. Unfortunately, the facility manager is often not informed of where their waste is being taken. This uncertainty can be removed by installing an on-site non-incineration technology, thereby eliminating long-range transportation of infectious waste and treating the waste close to the point of generation. This resource book discusses both on-site and off-site non-incineration technologies.

LAND DISPOSAL

After regulated medical waste is treated in a non-incineration technology and rendered unrecognizable (especially if required by law), the treated waste is generally discarded in a sanitary landfill. The treated waste should *not* be burned in an incinerator. In many cases, facilities mix their treated (non-infectious, non-hazardous) wastes with regular trash and send them to the municipal solid waste landfill.

However, some landfill operators may charge a higher tipping fee for treated waste that originated from regulated medical waste. In those cases, commingling regular trash with the treated waste could result in higher disposal costs. Others may require a certificate of treatment as documented proof that the waste has been decontaminated. Some landfills may not accept any treated waste at all. For aesthetic reasons, many landfills will not accept treated waste that is recognizable regardless of whether "unrecognizability" is required by regulations of that particular state.

Before a non-incineration technology is installed, the facility should first contact local landfill operators to ensure that the treated waste from the non-incineration technology will be acceptable and that the disposal fees are reasonable. Some state departments of health or departments of environmental protection may compile lists of landfills that accept treated waste. In the selection of

non-incineration technologies, facilities should consider those technologies which result in solid waste residues which, when disposed on land, would have the least long-term impact on the environment.

EVALUATING AND SELECTING NON-INCINERATION TECHNOLOGIES

Chapter 10 describes factors that should be considered in selecting a technology. Each facility must evaluate alternatives based on the technology's design and record of performance (e.g., throughput capacity, reliability, ease of use) as well as the needs of the facility (e.g., how much and what types of waste must be treated daily, space limitations in the facility, approval by local regulators, financial situation). An important performance criterion is a technology's efficacy of microbial inactivation.

Facilities should not rely solely on vendor data but should request a list of current users of the technology from the vendor. Facility managers should then contact as many of the users as possible to get their feedback on the technology. Valuable insight into the technology could be gained by talking to operators and facility managers. Maintenance and repair logs are indispensable in assessing reliability and maintenance requirements. One cannot overemphasize the importance of a site visit to a user's facility in order to evaluate the technology during actual use. For new or emerging technologies, it is essential to visit the manufacturer's facility and observe the technology in operation. State regulators are a source of data on air emissions and microbial inactivation testing which vendors are required to submit to receive approval in many states. These tests should be conducted by independent laboratories.

Health care facilities should also consider the possibility of using a combination of alternative technologies. A large technology to handle most of the waste may be supplemented by small non-incineration technologies designed to treat medical waste right at the point of generation, such as within a hospital department or on a hospital floor. Some technologies are small and portable

MICROBIAL INACTIVATION: STERILIZATION VS. DISINFECTION

The terms sterilization and disinfection refer to microbial inactivation and are used by vendors to describe the capabilities of their technologies. **Sterilization** is defined as the complete destruction of all forms of microbial life. In practice, however, the total elimination of all microbial life is difficult to prove and for this reason, the term sterilization is not used much in this report. Some references accept a 99.9999% reduction in the microbial population as "sterilization." **Disinfection** is the reduction of microbial contamination, especially the diminution of disease-causing microorganisms or pathogens. The State and Territorial Association on Alternative Treatment Technologies (STAATT) has defined quantitatively four levels of disinfection[2] in which Level IV is equivalent to a 99.9999% or greater reduction of vegetative bacteria, fungi, all viruses, mycobacteria, and *Bacillus stearothermophilus* spores. They recommend that alternative technology vendors meet at least the criteria for Level III disinfection (see Chapter 10).

Microbial inactivation is more appropriately expressed as a probability function, measured as reductions by factors of 10 in survival probability of a microbial population. Suspensions of resistant bacterial endospores are typically used as biological indicators: *Bacillus stearothermophilus* to test thermal inactivation, *Bacillus subtilis* for chemical inactivation, and *Bacillus pumilus* for irradiation. The test generally entails adding the biological indicator (usually a suspension of 2×10^{10} initial inoculum in a plastic tube) to a standardized medical waste load, running the waste load through the process, and collecting the biological indicator organisms after processing. The microorganism suspensions are plated to quantify microbial recovery. The first test run is done without microbial inactivation (e.g., no heat, no chemical disinfectant, no irradiation) to establish control conditions. The second run is done under normal operating conditions. Microbial populations are measured in colony forming units (cfu) per gram of waste solids. Calculations are then made to determine microbial inactivation in terms of the logarithms of the number of viable test microorganisms[3]. The resulting number is equal to the $\log_{10}$ reduction, also known as $\log_{10}$ kill.

A $\log_{10}$ kill of 6 is equal to a 99.9999% reduction or a one millionth (0.000001) survival probability or a 10^6 kill. A 4 $\log_{10}$ kill is equal to a 99.99% reduction or a one-ten thousandth (0.0001) survival probability or a 10^4 kill. These terms will be used in the discussion of non-incineration technologies.

enough to fit on a countertop while others are the size of a refrigerator. A combination of technologies might lower costs by decreasing the size requirements (and hence capital costs) of the larger technology, especially when the next-largest available capacity for the technology greatly exceeds the waste generation rate. Moreover, by treating infectious waste at the point of generation, hazards may be lessened as the quantities of biohazardous waste being transported around the facility are reduced.

Comparative economic analyses should take into account all major cost items, as presented in Chapter 11. The high capital cost of a technology may be compensated by lower annual operating costs, while the low purchase price of another technology may be offset by its high operating costs or by high installation costs. A comparative cash flow analysis is a useful tool for comparing technologies. Chapter 11 also discusses alternatives to purchasing.

This resource guide provides information that could help facility managers weigh the pros and cons of each technology. The technology descriptions presented here are based on information from vendors and other sources. An effort was made to verify the accuracy of vendor information where possible. However, health care facilities should conduct their own detailed technical and economic evaluations before making decisions. ***NOTE: Health Care Without Harm does not endorse any particular technology or brand name.***

NOTES

1. A. Pruss, E. Giroult and P. Rushbrook, *Safe management of wastes from health-care activities*, World Health Organization, Geneva, 1999.
2. These should not be confused with biosafety levels I to IV as defined in the Centers for Disease Control's guidelines for microbiological and biomedical laboratories.
3. Equations for computing the Log10 kill are found in STAATT I. "Technical Assistance Manual: State Regulatory Oversight of Medical Waste Treatment Technologies." State and Territorial Association on Alternative Treatment Technologies, April 1994; **www.epa.gov/epaoswer/other/medical/index.htm**

Chapter 3

Understanding the Waste Stream: A Necessary First Step

A waste analysis is an important step in selecting the non-incineration technology that best meets the needs of the facility. Furthermore, a waste stream analysis is a basis for identifying waste minimization options and establishing the degree of segregation. Through an analysis, the health care facility can establish whether or not some waste is being "overclassified" as biohazardous waste, and assess compliance with existing regulations on waste handling and disposal. A waste audit is a powerful tool for analyzing the hospital waste stream. This chapter describes the categories of medical waste and the waste audit. The problem of overclassification is highlighted.

CATEGORIES OF MEDICAL WASTE

Medical waste can be defined as waste generated as a result of diagnosis, treatment, and immunization of humans or animals. Some states include wastes generated as a result of biomedical research and the production and testing of biologicals. Unfortunately, there is no one common *specific* definition of what constitutes medical waste so each facility must determine this based on applicable federal, state, and local regulations.

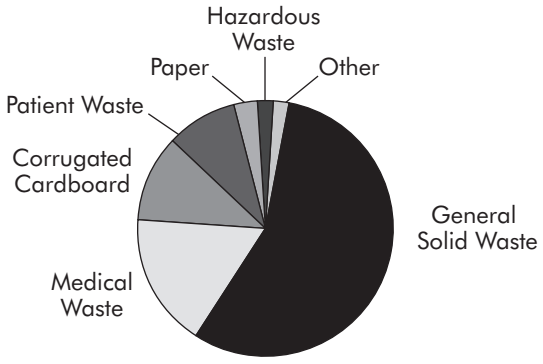
Because disposal of waste from health care facilities is driven by differing regulations, it is useful to categorize the overall waste stream into the following four categories:

1. **General trash** is garbage that is usually disposed of as municipal solid waste. This includes recyclable or compostable materials, as well as construction and demolition waste. Disposal is usually regulated by local ordinance.
2. **Regulated Medical Waste** or **Infectious waste** is generally defined as waste that is capable of producing infectious disease. Other terms used include biohazardous waste, potentially infectious medical waste, biomedical waste, or "red bag" waste. This category of waste includes pathological waste. Disposal is governed by state regulations.
3. **Hazardous waste** is defined as waste that may cause or significantly contribute to mortality or serious illness or pose a substantial hazard to human health and the environment if improperly managed or disposed of. Hazardous waste is subject to federal regulations under the Resource Conservation and Recovery Act (RCRA) as well as state hazardous waste laws. Under RCRA, the waste is hazardous if it contains one or more constituents listed under the law, exhibits one or more of four characteristics (toxic, reactive, ignitable, or corrosive), is a mixture that exhibits a hazardous characteristic or contains a "listed" waste, or is derived from a waste management process.
4. **Low-level radioactive waste** is waste that exhibits radiologic characteristics such as radioactive decay. It is subject to regulations of states and the U.S. Nuclear Regulatory Commission (NRC).

As shown in Figure 1, the typical breakdown of the overall hospital solid waste stream is as follows (Brunner, 1996)[1]: general solid waste – 56.4percent, medical waste – 17.5percent, corrugated cardboard – 10.9 percent, patient waste – 8.5 percent, paper – 3.1 percent, hazardous waste – 2.0 percent, wooden pallets – 0.4 percent, dry cell batteries – 0.4 percent, x-ray film – 0.3 percent, and other – 0.4 percent.

The rates of waste generation vary widely. One study of overall hospital waste found a range from 8 to 45 lbs/bed/day, with an average of 23 lbs/bed/day.[2] For other types of

FIGURE 1. BREAKDOWN OF TYPICAL HOSPITAL SOLID WASTE STREAM
[(Adapted from Brunner (1996)]



health care facilities, the following overall waste generation rates have been reported by Brunner[3]:

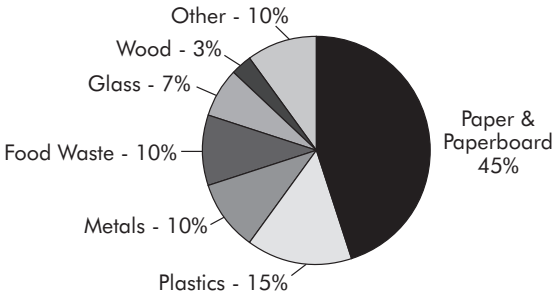
- Physicians' office — 5 lbs/patient/day (2.3 kg/patient/day)
- Nursing home — 3 lbs/person/day (1.4 kg/person/day)
- Laboratory — 0.5 lbs/patient/day (0.2 kg/patient/day)

General Trash

General trash from a hospital is similar to a combination of wastes from hotels, restaurants, and other institutions with lodging-type services, food services, data processing and administration, and facility operations. Solid waste is generally collected in trash bins or dumpsters and removed by haulers for disposal in a municipal landfill. Hospitals account for about 1 percent of all the municipal solid waste generated in the United States[4]. The composition of hospital municipal solid waste (shown in Figure 2) is typically: 45 percent paper and paperboard, 15 percent plastics, 10 percent food waste, 10 percent metals, 7 percent glass, 3 percent wood, and 10 percent other[5]. A closer examination of this waste reveals that many items are recyclable materials amenable to waste minimization.

FIGURE 2. HOSPITAL SOLID WASTE COMPOSITION

(From Bisson, McRae, and Shaner, 1993)



Regulated Medical Waste

The main focus of this resource guide is the treatment of regulated medical waste. **Regulated medical waste (infectious waste) is estimated to be 15 percent or less of the overall waste stream**. Each state has its own set of regulations defining and setting standards for the handling, treatment and disposal of regulated medical wastes. Each institution may further refine those definitions and standards depending on the nature of the facility, types of procedures, patients, and other site-specific conditions. Compounding the problem of classification is a confusing mix of medical waste categories based on type (e.g., microbiologic, pathologic, etc.), based on origin (e.g., isolation waste, surgery waste, laboratory waste, dialysis waste, etc.), and based on physical characteristics (e.g., soft wastes, hard metals, glass, plastics, liquids, etc.).

Many regulatory definitions of regulated medical waste are based on ten broad categories defined in a 1986 EPA guide on infectious waste management.[6] The ten general

TABLE 3-1. TEN CATEGORIES OF INFECTIOUS WASTE

	WASTE CATEGORY	DESCRIPTION
1	Cultures and Stocks	Cultures and stocks of infectious substances and associated biologicals
2	Anatomical Wastes (or Human Pathological Wastes)	Tissues, organs and body parts, including body fluids removed during surgery, autopsy, or other medical procedures
3	Human Blood, Blood Products, and Other Bodily Fluids	Discarded human blood, components or products of blood; items saturated with blood, blood products, or body fluids, or caked with dried blood
4	Sharps	Sharps including syringes, pipettes, scalpel blades, vials and needles; broken or unbroken glass
5	Animal Wastes	Discarded material including carcasses, body parts, body fluids, blood, or bedding from animals exposed to infectious substances
6	Isolation Wastes	Discarded material contaminated with blood, excretions, etc. from humans isolated to protect others from communicable diseases
7	Contaminated Medical Equipment	Medical equipment that was in contact with infectious substances
8	Surgery Wastes	Discarded material including soiled dressings, sponges, drapes, gowns, gloves, etc.
9	Laboratory Wastes	Wastes that was in contact with infectious substances such as slides and cover slips
10	Dialysis Wastes	Effluent and equipment that was in contact with blood of patients undergoing dialysis

TABLE 3-2. COMPARISONS OF CATEGORIES OF REGULATED MEDICAL WASTE[7]

CATEGORY	EPA–1986	EPA–1988	AORN	NY	CA
Cultures and stocks, or microbiologic wastes	✓	✓	✓	✓	✓
Pathological wastes including body parts	✓	✓	✓	✓	✓
Human blood, blood products, other body fluids	✓	✓	✓	✓	✓
Sharps (used and/or used)	✓	✓	✓	✓	✓
Animal wastes	✓	✓	✓	✓	✓
Isolation wastes	✓	✓			✓
Selected isolation wastes only			✓		
Contaminated medical equipment	✓				
Surgery wastes	✓				✓
Laboratory wastes	✓				✓
Dialysis wastes	✓				
Chemotherapy wastes					✓
Hazardous waste due to fixatives or pharmaceuticals					✓
Other designated categories				✓	

NOTE: Examples of what comprises each of the above categories may differ slightly.

categories and some typical descriptions are described in Table 3-1.

Differences exist between regulatory agencies on the descriptions of each category and on which of these categories should be considered infectious. Table 3-2 (above) compares the above categories with those defined by the Medical Waste Tracking Act in 1988, Association of Operating Room Nurses (AORN), New York State Department of Health, and California's Medical Waste Management Act.

Health care workers should be aware of how regulated medical waste is defined in their state and institution and any specific requirements pertaining to their disposal. Some states explicitly include cultures and stocks from research and industrial laboratories or from the production of biologicals. Several states may regulate only contaminated sharps, while others include unused sharps. Others include chemical waste, such as chemotherapy waste or waste contaminated with pharmaceutical compounds, as part of regulated medical waste. Some regulations include a provision allowing a state authority to designate additional categories not previously considered.

A survey of over 400 U.S. hospitals found that in the late 1980s almost all hospitals used the first six categories for designating infectious waste.[8] Table 3-2 shows that the first five categories are most commonly used. In recent years, several states have dropped the category of "isolation waste" while others have specified "selected isolation wastes" from patients with certain highly communicable, virulent diseases (defined by the CDC as class 4 etiologic agents such as Ebola and Lassa Fever).

Pathological waste, a component of regulated medical waste, generally includes tissue, organs, and body parts, specimens of body fluids, or body fluids removed during surgery, autopsy, or other medical procedures. About a dozen states require that body parts can only be disposed of by incineration or interment (burial). Some states specifically exclude teeth and contiguous structures of bone and gum under this category. Some regulations define laboratory waste to include specimen containers, slides and coverslips, disposable gloves, coats, and surgical gloves.

With regards to blood and body fluids, some states specify that the waste is regulated medical waste if it has free-flowing blood or fluids, or materials "saturated" with blood or fluids including caked blood. In addition to blood and blood components, body fluids of concern are defined in the OSHA Bloodborne Pathogen Standard as: "semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, saliva in dental procedures, any body fluid that is visibly contaminated with blood, and all body fluids in situations where it is difficult or impossible to differentiate between body fluids."[9] The OSHA rule does not deal with medical waste disposal *per se* but this definition has been used by facilities in determining their waste classification policies.

NOTE ON TECHNOLOGY DESCRIPTIONS AND TYPES OF WASTE TREATED: Broad categories will be used to describe the types of waste that a technology can handle. Most of these categories have been prescribed by the technology manufacturer. In vendor literature, an extra category of "soft wastes" is sometimes mentioned. Referring to cellulosic material such as gauze, cotton swabs, tissue paper, bandages, drapes, gowns, bedding, etc., soft wastes cut across other categories of waste. It is a useful category from the standpoint of mechanical destruction. Some technologies have grinders or shredders that can easily destroy needles, plastic containers, and glassware but may have difficulty handling soft cellulosic wastes which can wrap around shredder blades or shafts and hinder rotation. After determining what goes in a red bag, facilities should make sure that the selected technology can indeed treat each waste category from the perspective of mechanical destruction, microbial inactivation, emissions, regulatory acceptance, and safety.]

Regulated medical waste varies considerably in composition and characteristics as shown in Table 3-3. The following ranges of bulk densities in pounds per cubic feet have been reported[10]: human anatomical (50-75 lb/ft^3); plastics (5-144); gauze, swabs and other cellulosic material (5-62); alcohol and disinfectants (48-62); sharps (450-500); and bedding (175-225). *Shredded* infectious waste has a bulk density of around 20 lbs. per cubic feet but ranges widely from 10 to 150 lb/ft^3 depending on the composition.[11]

With regards to generation rates, the results of a nationwide survey of U.S. hospitals, as reported by W.A. Rutala and shown in Table 3-4, give a national average for infectious waste generation of 1.38 lbs/bed/day (0.627 kg/bed/day) or 2.29 lbs/patient/day (1.04 kg/patient/day). These are useful benchmark figures to help determine if a hospital is generating too much waste and could benefit from a vigorous waste minimization program.

TABLE 3-3. TYPICAL COMPOSITION AND CHARACTERISTICS OF INFECTIOUS WASTE[12]

Composition:	
Cellulosic Material (paper & cloth)	50 - 70%
Plastics	20 - 60%
Glassware	10 - 20%
Fluids	1 - 10%
Typical Characteristics:	
Moisture	8.5-17% by weight
Incombustibles	8% by weight
Heating Value	7,500 BTU/lb

Hazardous Waste

Different types of hazardous wastes are generated at health care facilities. Xylene, methanol, and acetone are frequently used solvents. Other chemicals include toluene, chloroform, methylene chloride, trichloroethylene, ethanol, isopropanol, ethylene acetate, and acetonitrile. Formaldehyde wastes (Formalin solutions) are found in pathology, autopsy, dialysis, nursing units, emergency room, and surgery, among others. Chemotherapy wastes (e.g., Chlorambucil, Cytoxin, Daunomycin, etc.) account for a large volume of hazardous waste in some hospitals[14]. Note that a few states specifically require incineration for chemotheraphy waste. Other hazardous wastes include photographic chemicals used in radiology, disinfecting solutions (e.g., glutaraldehyde), and maintenance and utility wastes in facility engineering. Mercury is a problem found in many facilities. Extensive lists of chemicals found in the health care industry are found in various references.[15]

TABLE 3-4. WASTE GENERATION RATES[13]

BED SIZE	TOTAL WASTE				INFECTIOUS WASTE
	kg/bed/day	lbs/bed/day	kg/patient/day	lbs/patient/day	(% of Total Waste)
< 100	2.59	5.71	5.13	11.3	13.3
100 - 299	4.70	10.4	7.16	15.8	15.0
300 - 499	5.67	12.5	8.63	19.0	14.9
> 500	5.83	12.8	7.69	16.9	14.9
Total Avg.	4.18	9.21	6.93	15.3	15.0

The storage, transportation, and disposal of hazardous waste are regulated under the federal Resource Conservation and Recovery Act which promulgates a cradle-to-grave approach to hazardous waste. Unplanned releases of hazardous substances fall under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) which requires reporting of certain releases depending on the type of substance and amount released. Hazardous-release emergency response and hazard communication are covered by the Emergency Planning and Community Right-to-Know Act (EPCRA).

Low-Level Radioactive Waste

Radioactive materials are used in diagnosis and treatment, as well as in clinical and research studies. Radionuclides used in nuclear medicine, clinical laboratories, and research laboratories have half-lives ranging from a few hours to several thousand years. Disposal methods include storage for decay (or "decay in storage") and shipment to an authorized radioactive waste disposal site. Radionuclides with short half-lives are generally stored in a secure facility long enough to allow decay to background levels (as confirmed by a radiation survey) and then disposed. Source reduction may be achieved by limiting the quantity of radioactivity purchased, using non-radioactive materials or shorter-lived radionuclides where possible, and designing laboratory procedures to reduce the volume of mixed waste.

MEDICAL WASTE AUDIT

A medical waste audit is a valuable tool. It can provide data on the sources of waste, compositions, generation rates, and waste flow within the facility. Information on waste handling practices, storage capacities, and waste traffic patterns may also be obtained, depending on how the audit is conducted. Medical waste audits involve preparation, data collection, analysis, and recommendations. Preparation entails defining goals, planning, enlisting the cooperation of key personnel and department heads, and a preliminary "walk-through" of the facility. Data can be collected in-house using self-audit forms and questionnaires. Another approach is to employ an outside consultant. The need for representative sampling determines the time period for data collection. Data collected for a few days provides a snapshot of the waste flow. Collecting data for two or more weeks requires greater staff effort but it may reveal important variations during different days of the week. A third approach is to install a computerized waste tracking system for long-term data collection. Several computer systems are available, such as the Walsh Waste Tracker[16]. A "waste sort" (separating and weighing components of waste collected during a time period) provides a more detailed analysis of waste composition and requires personal protective equipment.

From the data, one establishes the flow of waste and generation rates of every unit of the facility. Data on waste composition can be used to evaluate classification and segregation practices. A waste audit can uncover inefficiencies, estimate the true costs of waste management, and establish the levels of compliance to regulations and policies. Audits are essential in developing recommendations for cost reduction, waste minimization, improving compliance, and reducing risk and liability.

WORKER TRAINING ON WASTE CLASSIFICATION

The problem of dealing with medical waste is further compounded by so-called **over-classification**, referring to the problematic practice of health care workers dumping non-infectious materials, such as writing paper or unused disposables or even food waste, into red bags for disposal. Over-classification is a consequence of an over-conservative approach to infectious waste handling, ambiguous or nonexistent hospital policies, a lack of understanding of what constitutes potentially infectious waste, or simple expediency.

A clear policy, based on existing laws and guidelines, on what should be treated as infectious waste will help prevent over-classification. As noted earlier, the optimum number and proper placement of red bag and regular trash containers can help reduce this problem. Practical training and education of employees is vital, in addition to regular monitoring and evaluation to prevent over-classification. This problem also suggests the importance of a dedicated waste management staff, rather than relying on volunteers, to do the regular monitoring, evaluation, and training needed.

After an analysis of the hospital's waste stream is completed and any problems of over-classification are eliminated, the facility is in a better position to determine what kind and what size of non-incineration treatment technology would best meet its needs.

NOTES

1. C. R. Brunner, *Medical Waste Disposal.* (Reston, VA: Incinerator Consultants Incorporated, 1996).
2. U.S. Environmental Protection Agency. "Hospital Waste Combustion Study: Data Gathering Phase." EPA-450/3-88-017. (Springfield, VA: National Technical Information Service, December 1988).
3. C.R. Brunner, *loc cit.*
4. K.D. Wagner, "Defining and Characterizing the Waste Stream of Healthcare Facilities," Chapter 2 in K.D. Wagner, C.D. Rounds, and R.A. Spurgin, Editors. *Environmental Management in Healthcare Facilities*. (Philadelphia, PA: W.B. Saunders Company, 1998).
5. R.C. Fenwick, American Hospital Association conference on hospitals and the environment, May 1991; cited in C.L. Bisson, G. McRae, and H.G. Shaner. *An Ounce of Prevention: Waste Reduction Strategies for Health Care Facilities*. (Chicago, IL: American Society for Healthcare Environmental Services, 1993)
6. *Guide for Infectious Waste Management*, EPA/530-SW-86-014, Washington, DC, May 1986.
7. Sources: EPA – 1986 (Guide for Infectious Waste Management, EPA/530-SW-86-014, Environmental Protection Agency, Washington, DC, May 1986); EPA – 1988 (Medical Waste Tracking Act of 1988, 42 USC 6992), AORN (AORN Position Statement, Association of Operating Room Nurses, Denver, CO, March 14, 1994); NY (Public Health Law 1389 as revised by Chapter 438 of the Laws of 1993); CA (Medical Waste Management Act, California Health and Safety Code, Sections 117600-118360).
8. W.A. Rutala, W. Odette, and G. Samsa, *Infect. Waste Management*, 4(4), 198 (1989).
9. "Occupational Exposure to Bloodborne Pathogens," Occupational Safety and Health Administration Standard found in 29 CFR Part 1910.1030.
10. *Incinerator Design and Operating Criteria*. Volume II. (Ontario, Canada: Ontario Ministry of the Environment, October 1986).
11. J. Emmanuel, unpublished data based on measurements made in 1994 and other sources.
12. U.S. Environmental Protection Agency. "Operation and Maintenance of Hospital Medical Waste Incinerators." EPA-450/3-89-002. (March 1989); C.R. Brunner, *Medical Waste Disposal.* (Reston, VA: Incinerator Consultants Incorporated, 1996).
13. W.A. Rutala, *JAMA*, Vol. 262 (12), September 22, 1989; W.A. Rutala, W. Odette, and G. Samsa, *Infect. Waste Management*, 4(4), 198 (1989).
14. One study found that hospitals, clinics, and surgery centers reported average ranges of chemotherapy waste from 13 to 69 percent of total wastes produced. *Report to the Legislature: Washington State Infectious Waste Project and Attachments*. Olympia, WA: Washington State Department of Ecology, December 30, 1989.
15. R.T. Gun et al., "Report of the DSHEFS Task Force on Hospital Worker Health," National Institute for Occupational Safety and Health (U.S. Department of Health and Human Services), Cincinnati, OH, December 1985; A. R. Turk, "Managing Chemical Hazards," Chapter 15 in K.D. Wagner, C.D. Rounds, and R.A. Spurgin, Editors. *Environmental Management in Healthcare Facilities*. (Philadelphia, PA: W.B. Saunders Company, 1998); and Hospitals for a Healthy Environment, www.h2e-online.org.
16. Information provided in 1997 by Walsh Integrated Environmental Systems, Inc. (Montreal, Quebec) and vendor's website.

Chapter 4

Non-incineration Technologies: General Categories and Processes

Non-incineration treatment technologies can be classified in many ways—such as according to size, purchase price, types of waste handled, or market share. In this chapter, the technologies will be categorized based on the fundamental processes used to decontaminate waste. The four basic processes are:

1. Thermal processes
2. Chemical processes
3. Irradiative processes
4. Biological processes

The majority of non-incineration technologies employ the first two processes listed above. Presented below are each of these processes, as well as **mechanical processes** which supplement the four fundamental processes.

THERMAL PROCESSES

Thermal processes are those that rely on heat (thermal energy) to destroy pathogens in the waste. This category is further subdivided into low-heat, medium-heat, and high-heat thermal processes. This further subclassification is necessary because physical and chemical mechanisms that take place in thermal processes change markedly at medium and high temperatures.

Low-Heat Thermal Processes

Low-heat thermal processes are those that use thermal energy to decontaminate the waste at temperatures insufficient to cause chemical breakdown or to support combustion or pyrolysis. In general, low-heat thermal technologies operate between 200°F to about 350°F (93°C -177°C). The two basic categories of low-heat thermal processes are wet heat (steam) and dry heat (hot air) disinfection. Wet heat treatment involves the use of steam to disinfect waste and is commonly done in an autoclave (see Chapter 5). Microwave treatment is essentially a steam disinfection process since water is added to the waste and disinfection occurs through the action of moist heat and steam generated by microwave energy[1]. In dry heat processes, no water or steam is added. Instead, the waste is heated by conduction, natural or forced convection, and/or thermal radiation using infrared heaters.

Medium-Heat Thermal Processes

Medium-heat thermal processes take place at temperatures between 350 to 700°F (177°C-370°C) and involve the chemical breakdown of organic material. These processes are the basis for relatively new technologies. They include reverse polymerization using high-intensity microwave energy and thermal depolymerization using heat and high pressure.

High-Heat Thermal Processes

High-heat thermal processes generally operate at temperatures ranging from around 1,000°F to 15,000°F (540°C-8,300°C) or higher. Electrical resistance, induction, natural gas, and/or plasma energy provide the intense heat. High-heat processes involve chemical and physical changes to both organic and inorganic material resulting in total destruction of the waste. A significant change in the mass and volume of the waste also occurs. For example, low-heat thermal technologies that rely on shredders or grinders to reduce size decrease waste volume by about 60 to 70 percent, compared to 90 or 95 percent with high-heat thermal processes.

CHEMICAL PROCESSES

Chemical processes employ disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, or dry inorganic chemicals. To enhance exposure of the waste to the chemical agent, chemical processes often involve shredding, grinding, or mixing. In liquid systems, the waste may go through a dewatering section to remove and recycle the disinfectant. Besides chemical disinfectants, there are also encapsulating compounds that can solidify sharps, blood, or other body fluids within a solid matrix prior to disposal. One developing technology uses ozone to treat medical waste, and others utilize catalytic oxidation. A novel system uses alkali to hydrolyze tissues in heated stainless steel tanks.

IRRADIATIVE PROCESSES

Irradiation-based technologies involve electron beams, Cobalt-60, or UV irradiation. These technologies re-

quire shielding to prevent occupational exposures. Electron beam irradiation uses a shower of high-energy electrons to destroy microorganisms in the waste by causing chemical dissociation and rupture of cell walls. The pathogen-destruction efficacy depends on the dose absorbed by the mass of waste, which, in turn, is related to waste density and electron energy. Germicidal ultraviolet radiation (UV-C) has been used as a supplement to other treatment technologies. Irradiation does not alter the waste physically and would require a grinder or shredder to render the waste unrecognizable.

BIOLOGICAL PROCESSES

Biological processes employ enzymes to destroy organic matter. Only a few non-incineration technologies have been based on biological processes.

MECHANICAL PROCESSES

Mechanical processes—such as shredding, grinding, hammermill processing, mixing, agitation, liquid-solid separation, conveying (using augers[2], rams, or conveyor belts), and compaction – supplement other treatment processes. Mechanical destruction can render the waste unrecognizable and is used to destroy needles and syringes so as to minimize injuries or to render them unusable. In the case of thermal- or chemical-based processes, mechanical devices such as shredders and mixers can also improve the rate of heat transfer or expose more surfaces to chemical disinfectants. Mechanical processes can add significantly to the level of maintenance required.

A mechanical process is supplementary and cannot be considered a treatment process *per se.* **Unless shredders, hammermills, and other mechanical destruction processes are an integral part of a closed treatment system, they should not be used before the waste is decontaminated.** Otherwise, workers would be exposed to pathogens released to the environment by mechanical destruction. If mechanical processes are part of a system, the technology should be designed in such a way that the air in and from the mechanical process is disinfected before being released to the surroundings. It is especially important for air to be drawn into the mechanical process (away from the inlet) when waste is being fed. This is often done using a draft fan which maintains a negative pressure in the mechanical processing chamber; air taken from the mechanical process passes through the disinfection chamber or through a high efficiency particulate air (HEPA) filter before being released to the environment. Shredders, grinders, and hammermills are commonly used size-reduction equipment. Other terms, such as granulators, particlizers, and cutters, are also used. In general, size reduction is accomplished by shearing the material between two surfaces (as in shredders) or by impact against a solid surface (as in hammermills). A screen is usually added to control the size of particles that exit the device. Sometimes, a ram is used to push the waste through the shredder or grinder.

Shredders are designed with hardened steel cutting knives, hooks, disks, or blades mounted on rotating shafts. These knives cut against stationary knives on the casing (single-shaft shredders) or against other knives mounted on one or more counter-rotating shafts (multiple-shaft shredders). Because waste material can get lodged between the blades, many shredders used for medical waste are equipped with reverse action, e.g., when an overload occurs, the normal rotating motion is stopped and a reverse rotating motion is used to clear the obstruction. This action may be repeated several times automatically. If the blockage is still not removed, the shredder shuts off and the operator is sent an audio-visual or electronic alert. Removing the blockage then requires manual operation. Shredders generally operate at low speed and high rotation force.

Grinders refer to size-reduction equipment using a series of rollers that operate at high speed. Terms like crusher and pulverizer are also used. When the rollers are equipped with teeth or knives, they operate much like multiple-shaft shredders, which is why the terms shredder and grinder are sometimes used interchangeably. A **hammermill** has a rotating shaft with swinging T-shaped steel hammers or beaters mounted on it. As the hammermill rotates at high speed, waste is crushed by the hammers against a plate. Hammermills tend to be noisier and use more energy.

All these devices are maintenance-intensive. Hammers need periodic resurfacing, dull cutting knives need sharpening, and worn or broken shredder blades need to be replaced. Some shredders and grinders have a breakaway pin to protect the shaft during those rare but inevitable times when a prosthetic steel joint ends up in the shredder. When that happens, it is safer and easier to replace the breakaway pin than to replace the entire shaft. However, hard metal objects would likely cause shredder blades to break or chip especially if the device has automatic reverse action. Mechanical devices should have an alternative way of disinfecting the waste in the event that the equipment needs to be opened for repair; otherwise service personnel could be exposed to pathogens. In addition to metal parts that can dull or chip shredder blades, soft waste such as cloth, gauze, or moist paper can also cause problems by wrapping around shredder blades and shafts.

Some hot (molten or softened) plastics can flow around shredder parts and harden upon cooling. Some equipment can handle these problems better than others. When considering a technology that has a grinder or shredder, facilities should evaluate the size-reduction equipment based on real-world experiences of other facilities dealing specifically with medical waste. They should also inquire about: safety; overload protection; how the equipment handles temporary obstructions; alternative disinfection procedures during repairs; average life span of blades, cutting knives, hammers, and other items that wear out; cost of sharpening and of their replacement; and preventive maintenance procedures, among others. The amount of wear depends on the types of waste treated. For example, treating sharps may result in more frequent replacement than treating soft wastes. Access to repair and maintenance records of facilities that have installed the specific device could be valuable in evaluating the reliability of different size-reduction equipment.

Unrecognizability

Mechanical destruction processes render the waste unrecognizable. Some states require that treated medical waste must be rendered unrecognizable before landfilling. Other states only specify that body parts be unrecognizable. Many states require that sharps be broken (or ground up), made unusable, and/or packaged in puncture-resistant containers. Facilities should check with their state agencies to determine if any of these requirements applies to them.

Even in states where there is no "unrecognizability" requirement, facilities need to check with local municipal landfill operators. In places where treated medical waste can remain recognizable, landfill operators may refuse to accept the waste. Some groups have argued for "unrecognizability" for aesthetic reasons, as an added indication that the waste has been treated, or because rendering the waste unrecognizable usually entails a reduction in waste volume—an obvious benefit in areas where landfill capacities are dwindling.

NON-INCINERATION TECHNOLOGIES BY CATEGORIES

Table 4-1 lists some non-incineration technologies according to category. These technologies range from small units for use at or near the point of generation to high-capacity systems for large medical centers or regional facilities.

TABLE 4-1. NON-INCINERATION TREATMENT TECHNOLOGIES FOR MEDICAL WASTE

NON-INCINERATION TECHNOLOGIES	TECHNOLOGY VENDORS
LOW-HEAT THERMAL PROCESSES	
Autoclave or Retort	Bondtech (Somerset, KY)
Autoclave or Retort	Environmental Techtonics Corp. (Southampton, PA)
Autoclave or Retort	Mark-Costello (Carson, CA)
Autoclave or Retort	Sierra Industries (Santa Ana, CA)
Autoclave or Retort	SteriTech (Bloomington, IN)
Autoclave or Retort	Tuttnauer (Ronkonkoma, NY)
Vacuum-Steam-Compaction	San-I-Pak (Tracy, CA)
Steam-Mixing-Fragmenting/Drying/ Shredding	Tempico (Madisonville, LA)
Shredding/Steam-Mixing/Drying, Chemical	Sterile Technologies Inc. (West Chester, PA)
Shredding-Steam-Mixing/Drying	Antaeus Group (Hunt Valley, MD)
Shredding-Steam-Mixing/Drying	Ecolotec (Union Grove, AL)
Steam-Mixing-Fragmenting/Drying	Hydroclave Systems Corp. (Kingston, Ontario, Can.)
Pre-Shredding/Steam-Mixing	Aegis Bio-Systems (Edmond, OK)
Shredding/Steam-Mixing-Compaction	LogMed (Erdwich ZerkleinerungsSysteme GmbH
Microwave Treatment	Sanitec (West Caldwell, NJ)
Microwave Treatment	Sintion/CMB (Austria)
Electro-Thermal Deactivation	Stericycle (Lake Forest, IL)
Dry Heat Treatment	KC MediWaste (Dallas, TX)
Dry Heat Treatment	Demolizer

CONTINUED ON THE FOLLOWING PAGE >>

TABLE 4-1. NON-INCINERATION TREATMENT TECHNOLOGIES FOR MEDICAL WASTE (CONTINUED)

NON-INCINERATION TECHNOLOGIES	TECHNOLOGY VENDORS
MEDIUM-HEAT THERMAL PROCESSES	
Reverse Polymerization	Environmental Waste International (Ajax, Ontario)
Thermal Depolymerization	Changing World Technologies (West Hempstead, NY)
HIGH-HEAT THERMAL PROCESSES	
Pyrolysis-Oxidation	Oxidation Technologies (Annapolis, MD)
Plasma Pyrolysis	DayStar/Prometron (Tokyo, Japan)
Plasma Pyrolysis	Electro-Pyrolysis, Inc. (Wayne, PA)
Plasma Pyrolysis	HI Disposal Systems (Indianapolis, IN)
Plasma Pyrolysis	Integrated Environmental Systems (Richland, WA)
Plasma Pyrolysis	MSE Technology Applications (Butte, MT)
Plasma Pyrolysis	Plasma Pyrolysis Systems (Stuyvesant Falls, NY)
Plasma Pyrolysis	Startech Environmental Corp. (Wilton, CT)
Plasma Pyrolysis	Unitel Technologies (Mt. Prospect, IL)
Plasma Pyrolysis	Vance IDS/Bio Arc (Largo, FL)
Plasma Pyrolysis	Vanguard Research Inc. (Lorton, VA)
Induction-Based Pyrolysis	Vanish Technologies/LFR (Raritan, NJ)
Laser-Based Pyrolysis	Anara Group (Las Vegas, NV)
Superheated Steam Reforming	Duratek (Columbia, MD)
Advanced Thermal Oxidation	NCE Corporation (Carrollton, TX)
CHEMICAL PROCESSES	
Sodium Hypochlorite-Hammermill	Circle Medical Products (Indianapolis, IN)
Sodium Hypochlorite-Shredding (mobile)	MedWaste Technologies Corp. (Houston, TX)
Chlorine Dioxide-Shredding/Grinding	Encore/Medical Compliance (El Paso, TX)
Ozonation	Lynntech (College Station, TX)
Electrocatalytic Wet Oxidation	MeDETOX/Delphi Research (Albuquerque, NM)
"Stericid"-Shredding-Mixing	MCM Environmental Technologies (Gilboa, Israel)
Dry Inorganic Chemical-Shredding	Positive Impact Waste Solutions (Pearland, TX)
Dry Inorganic Chemical-Shredding	Premier Medical Technology (Houston, TX)
Peracetic Acid-Grinding	Ecocycle 10/STERIS Corp. (Mentor, OH)
Alkaline Hydrolysis	WR^2 (Indianapolis, IN)
IRRADIATION PROCESSES	
Electron Beam	BioSterile Technology (Fort Wayne, IN)
Electron Beam-Shredding	U. Miami E-Beam (Coral Gables, FL)
BIOLOGICAL PROCESSES	
Enzyme-Based Treatment/Extrusion	Bio Conversion Technologies, Inc. (Norcross, GA)

N/a = not available

NOTE: The above technologies are described in subsequent chapters. Health Care Without Harm does not endorse any technology, company, or brand name. These technologies are listed here as examples of alternatives to traditional incineration. HCWH does not claim that this is a comprehensive listing.

Non-Incineration Technologies for Off-Site Treatment

Most of the technologies presented in this report can be installed on-site at a hospital or medical center. Many technology vendors offer multiple models with different capacities to meet the needs of small to large health care facilities. The following vendors manufacture units with high throughput rates suitable for off-site regional treatment centers:

- Bondtech
- Environmental Techtonics Corporation
- Mark-Costello
- Sierra Industries
- Tuttnauer
- San-I-Pak
- Tempico
- Sterile Technologies Inc.
- Hydroclave Systems Corp.
- Aegis Bio-Systems
- Sanitec
- Bio-Oxidation/Oxidation Technologies
- Electro-Pyrolysis, Inc.
- Integrated Environmental Systems
- Startech Environmental Corporation
- Anara Group
- Circle Medical Products
- Positive Impact Waste Solutions
- Premier Medical Technology
- Bio Conversion Technologies, Inc.

The following technologies are primarily for off-site regional treatment facilities:

- Environmental Techtonics Corporation
- Aegis Bio-Systems
- Stericycle
- HI Disposal Systems
- Anara Group
- Encore/Medical Compliance
- Matrix
- Bio Conversion Technologies, Inc.

SOURCES OF INFORMATION

The alternative treatment technology industry is relatively new, compared to the incineration industry. As with any new dynamic market, technologies come and go. Many new technologies that existed only a year or two ago are no longer in business. Furthermore, technology designs have evolved rapidly in response to changing needs and requirements. For this reason, **it is important to contact technology vendors to get the latest and most accurate data and specifications on non-incineration technologies.**

The technology descriptions that follow are based on vendor information (such as vendor websites, brochures, and personal communications), non-proprietary technical data provided by vendors or manufacturers, evaluations by non-profit institutions and private consultants (such as the author), research by academic institutions, government studies, and other sources. An effort was made to corroborate or verify the accuracy of vendor information where possible. Claims by vendors that were deemed misleading or dubious were left out of the descriptions. The information presented is intended to provide an overview and general understanding of non-incineration technologies. Health care facilities, however, should conduct their own technical and economic evaluations of the technologies before deciding on any particular option.

NOTES

1. Various studies show that the lethal effect of microwaves on microbial organisms is primarily due to moist heat; without water or steam, microwave energy alone results in no significant cell inactivation. See, for example, G.R. Vela and J.F. Wu. *Applied and Environmental Microbiology*, 37(3), 552, 1979.
2. An auger is essentially a large screw that rotates inside a cylinder, thereby moving the waste forward.

Chapter 5

Low-Heat Technologies: Autoclaves, Microwaves, and Other Steam-Based Systems

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°F). 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 5-1. PROPERTIES OF SATURATED STEAM

ABSOLUTE PRESSURE		GAUGE PRESSURE	TEMPERATURE	
kPa	psia	psig	°F	°C
100	14.7	0	212	100
115	17	2.3	219	104
130	20	5.3	228	107
180	25	10	240	117
200	27	12	244	120
250	34	19	258	127
300	50	35	281	134
350	60	45	293	139
400	70	55	303	144
600	100	85	328	159

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 chemotherapeutic 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[1] 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/m^3. 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[2]. 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 that 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 $\log_{10}$ 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[3]

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 3'5" 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[4]

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.*

Mark-Costello[5]

Description
Mark-Costello has been making waste treatment autoclaves for over two decades. Their units are capable of reaching a maximum working pressure of 75 psi (320°F). Waste is collected and put into autoclavable bags that may be placed in special carts or drawers. (Alternatively, waste can be put into carts with autoclavable cart liners.) Once the waste is brought into the vessel, an automatic key-lock system controls the process and documents it on a chart recorder. A typical system exposes medical waste to steam at 275°F for one hour. The waste is removed when the vessel cools. Mark-Costello has installed over 250 units.

Selected Models-Capacities (in lbs/cycle)
Model AS36 – 225 lb/cycle; *AS47* - 450; *AS58* - 565; *AS510* - 750; *AS515* - 1,125; *AS634DD* - 3,000

Approximate Dimensions
The vessels are cylindrical in shape. Dimensions: *AS36* – 3' dia. x 6' long; *AS47* – 4' dia x 7' long; *AS58* – 5' dia x 8' long; *AS510* – 5' dia x 10' long; *AS515* – 5' dia x 15' long; *AS634DD* – 6' dia x 34' long

Energy Consumption
Small and medium units use about 100 lbs of steam per cycle; large standard units use about 150-200 lbs per cycle.

Typical Installation Requirements
Steam – 60 psig regulated steam supply; electrical – 115 V 1-phase 5A; Floor drain or floor sink connected to sanitary sewer; exit for vent line and blowdown line

Features & Options
In addition to internal tracks and ramps for the autoclave, Mark-Costello also offers standard carts, autoclavable carts (stainless steel or aluminum), hydraulic cart dumpers, pullout drawers, conveyors, and a full line of waste compactors (stationary and self-contained; 2 to 20 cu. yds) and waste handling equipment.

Stage of Commercialization
Fully commercialized

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

Approximate Costs
Approximate capital costs range from about $26,00 for *AS36*; $34,000 for *AS47*; $38,000 for *AS510*; to $41,000 for *AS515*. Autoclave carts are about $1,100-$1,500.

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[6]

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[7]

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[8]

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
Autoclave 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 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[9], 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[10]

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 6'11-11/16" D; *#347* – 7'8-3/16" H x 32'1" W x 5'3-5/8" D; *#358* – 10'3/4" H x 36'8" W x 6'11-11/16" 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 P.O. 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.*

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[11] 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[12] 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[13]

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., P.O. 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 WR[2] (described under chemical-based systems).

STI Chem-Clav[15]

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.*

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[16]

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[17]

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.[18]

Hydroclave[19]

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" / 23,200 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*[20]

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 in 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 (Kolpingstrassa 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 ("particlizer"), 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.

- *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[21] 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[22] 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[23] 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.[24] 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[25] 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, Staphlococcus 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[26] 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).

Sanitec[27]

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 $600,00

Vendor Information
Sanitec International Holdings, 26 Fairfield Place, West Caldwell, NJ 07006; Ph. 973-227-8855; Fax 973-227-9048; 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[28]

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 microwave 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

Vendor Information
CMB/Christof Group, Plabutscherstrasse 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.*

DIELECTRIC HEATING

Stericycle uses a heating process based on "electro-thermal deactivation."[29] 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.

A report[30] 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

1. K. Owen, K. Leese, L. Hodson, R. Uhorchak, D. Greenwood, D. VanOsdell, and E. Cole. "Control of Aerosol (Biological and Nonbiological) and Chemical Exposures and Safety Hazards in Medical Waste Treatment Facilities." (Cincinnati, OH: National Institute of Occupational Safety and Health, November 1997).
2. See for example: J.L. Lauer, D.R. Battles, and D. Vesley, "Decontaminating infectious laboratory waste by autoclaving," *Appl. Envron. Microbiol.* 44 (3), 690-694, September 1982; W.A. Rutala, M.M. Stiegeland, and F.A. Sarubbi, Jr., "Decontamination of laboratory microbiological waste by steam sterilization," *Appl. Environ. Microbiol.* 43, 1311-1316, June 1982; E. Hanel, Jr., "Chemical Disinfection" in *Control of Biohazards in the Research Laboratory*, Course Manual, School of Hygiene and Public Health, Johns Hopkins University, Baltimore, MD, 1981; Herman Koren, *Environmental Health and Safety*, Pergamon Press, NY, 1974
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 Tuttnauer from 1994 to 1997, and personal communications with Robert Basile.
9. E.C. Cole, T.K. Pierson, D. R. Greenwood, K.E. Leese, and K.K. Foarde, "Evaluation of Medical Waste Treatment Technologies: Final Report," prepared for the Office of Solid Waste, U.S. EPA, RTI Report number 5400-005/01 F, Research Triangle Institute, Research Triangle Park, NC, January 1993.2
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.
11. Cited in W.L. Turnberg. *Biohazardous Waste: Risk Assessment, Policy and Management.* (New York, NY: John Wiley & Sons, Inc. 1996).
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.
16. Based on vendor website, press releases, technical presentations by Dr. Sanford Glazer in 1993, vendor literature from 1996 to 1998, and personal communication with William Norton.
17. Based on vendor website, vendor material provided in 1999, and personal communications with Wolf von Lersner and Michael Neubauer.
18. S. Springthorpe and S. Sattar, "Performance of the Hydroclave for Determination of Biomedical Waste: Trials conducted on unit installed at Kingston General Hospital," University of Ottawa, report submitted to Hydroclave Systems and Ontario Ministry of Health, November 1995; "Preliminary Evaluation of

Volatile Organic Compounds Associated with a Hydroclave Cycle at Kingston General Hospital," Phoenix OHC, Inc., November 1998.

19. Based on vendor website, presentation by R. Vanderwall, and vendor brochure provided in 1997.
20. Based on vendor website, vendor brochures provided by Aegis Bio-Systems in 1997, and personal communication with Ron Mercer.
21. "Evaluation of the ABB Sanitec Microwave Disinfection System for Aerosol Emissions," North American Laboratory Group, New Brittain, CT, 1992; "ABB Sanitec Microwave Disinfection System - Ability to Control Aerosol Emissions: Synopsis of Evaluations," a summary of aerosol emission studies provided by Sanitec, November 1, 1996.
22. E. Cole. "Chemical and Biological Exposures and Safety Hazards in Medical Waste Treatment Facilities: An Assessment of Alternative Technologies." Vol. 98/2, No. 9 (Cedex, France: International Healthcare Waste Network (IhcWaN), August 31, 1998).
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.
26. G.R. Vela and J.F. Wu, *Appl. Environ. Microbiol.*, 37(3), 552, 1979; L. Najdovski, A.Z. Dragas, and V. Kotnik, *J. Hosp. Infect.* (19), 239, 1991.
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.
29. Much of the description of Stericycle's ETD is based on vendor website, vendor literature, and Chapter 10 in W.L. Turnberg. *Biohazardous Waste: Risk Assessment, Policy and Management.* (New York, NY: John Wiley & Sons, Inc. 1996).
30. "Profile of Stericycle, Inc.: An Environmental Assessment of the Nation's Largest Medical Waste Company," by Health Care Without Harm, 2001.

Chapter 6

Low-Heat Thermal Technologies: Dry-Heat Systems

Just as circulating hot-air ovens have been used to sterilize glassware and other reusable instruments, the concept of dry-heat disinfection has been applied to treatment of medical waste. In **dry-heat processes**, heat is applied without adding steam or water. Instead, the waste is heated by conduction, natural or forced convection, and/or by thermal radiation. In force-convection heating, air heated by resistance heaters or natural gas, is circulated around the waste in the chamber. In some technologies, the hot walls of the chamber heat the waste through conduction and natural convection. Other technologies use radiant heating by means of infrared or quartz heaters. As a general rule, dry-heat processes use higher temperatures and longer exposure times than steam-based processes but the time-temperature requirements actually depend on the properties and size of the objects being treated.

The toroidal mixing bed dryer using high-velocity heated air (a technology designed for hospitals and offered by KC MediWaste) and the Demolizer (a small table-top device for hospital departments, clinics, medical offices, and other small volume generators) will be described in this chapter.

HIGH VELOCITY HEATED AIR

Overview of the Technology

The KC MediWaste System evolved out of efforts by Cox Sterile Products, Inc. to develop a rapid dry-heat sterilizer coupled with their adaptation of the Torbed technology by Torftech (UK), a dry-heat technology used in the processing of minerals, foods, and wastes. The first installation of the KC MediWaste technology is at the Mercy Health Center in Laredo, Texas.

The heart of the system is an air-tight stainless steel chamber into which shredded medical waste is introduced and exposed to high velocity heated air pumped into the bottom of the chamber through a ring of vanes or slots similar in design to turbine blades. The hot air is directed in a way that causes the waste particles to rotate turbulently around a vertical axis in a toroidal mixing action. Under these conditions, high rates of heat transfer take place. Within four to six minutes, dry unrecognizable waste is ejected. The waste can then be disposed of at a regular landfill.

How It Works

The operation of the KC MediWaste System is as follows:

- *Waste loading*: Red bags are loaded into carts that attach to a lifter-dumper which automatically opens an air-lock hopper door and empties the waste into the shredder hopper while maintaining a negative pressure to minimize aerosolization.
- *Internal shredding*: The waste is shredded to a relatively uniform size of about 19 mm (3/4 inch), passing through a changeable screen and collecting in a surge vessel.
- *Metering*: The amount of waste introduced into the chamber is controlled by a gate valve. It opens automatically when the chamber is empty, allowing a new batch to be processed. The chamber operates under a negative pressure.
- *Dry-heat treatment*: After the shredded waste is pulled into the chamber, it is exposed to high-velocity heated air (at about 171°C or 340°F). The temperature in the chamber drops initially but recovers in about four minutes.
- *Discharge*: At the end of a pre-set time, the dump door of the chamber is opened expelling the waste in a matter of seconds. The treated waste falls into a compactor dumpster under the chamber.
- *Compaction and disposal*: The dry, unrecognizable waste is compressed and put into sealed containers ready for disposal at a sanitary landfill.

Types of Waste Treated

The types of waste treated in the KC MediWaste System are somewhat similar to those treated in autoclaves or microwaves: 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. In addition, liquids such as blood and body fluids can also be treated in the unit. It is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment in this technology.

Volatile and semi-volatile organic compounds, chemotherapeutic wastes, mercury, other hazardous chemical wastes, and radiological wastes should *not* be treated in a dry heat system.

Emissions and Waste Residues

Exhaust gases from the air pulled from the shredder hopper are filtered through a high-efficiency particulate air (HEPA) filter and a carbon filter to remove aerosolized pathogens and odors prior to discharge. The hot air from the chamber is cooled in a venturi scrubber which also removes particulates. There are some odors in the vicinity of the unit.

The conditions in the chamber do not support combustion. Therefore, the air emissions are minimal as long as waste streams are properly segregated to prevent hazardous chemicals from being fed into the chamber. Since there are no combustion byproducts, the State of Texas has granted KC MediWaste exemptions from air quality permitting procedures. There is also no liquid effluent from the chamber.

The waste residue is dry and unrecognizable. With shredding and compaction, the waste volume is reduced by about 80% and has been accepted for disposal at a solid waste landfill. The mass of the dry treated waste is also reduced, depending on the amount of moisture it had contained.

Microbial Inactivation

Microbiological tests using *B. subtilis var. niger* strips (the variety traditionally used to test for dry-heat resistance) introduced into the chamber showed a 6 log10 kill in about three minutes.[1]

Advantages and Disadvantages of the Technology

Heated air technology has the following advantages:

- The basic design of the treatment chamber is simple (it has been described as a popcorn popper). The Torbed itself has been used for many years in other applications.
- If proper precautions are taken to exclude hazardous material, the emissions from the dry heat system are minimal.
- The technology can treat waste with varying moisture content, including blood and body fluids.
- There are no liquid effluents.
- The internal shredder and post-treatment compactor reduce waste volume by about 80 percent.
- The technology is automated and easy to use. It requires one operator.
- A combination of HEPA and carbon filters, and a venturi scrubber keep odors to a minimum.
- The treated waste is dry, unrecognizable, and compact.

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.
- Some slight odors may be generated near the compactor.
- Any large, hard metal objects may interfere with the shredder.
- The KC MediWaste Processor is a relatively new technology.

Other Considerations

Below are some suggestions to consider when selecting this dry heat system:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in a dry-heat treatment system.
- The carts should be disinfected prior to reuse. A steam cleaning system is available.
- The Laredo, TX unit has a vertical configuration. Other designs are possible.
- Maintain records of biological indicator tests, treatment parameters, preventive maintenance activities, and periodic inspections.
- Provide worker training to include: a basic understanding of the dry-heat systems, standard operating procedures, occupational safety, record keeping, identifying waste that should not be treated in the unit, recognizing technical problems, periodic maintenance schedules, and contingency plans (e.g., what to do in case of a spill or power outage).

KC MediWaste[2]

Description

(See above)

Models-Capacities

Standard model capacity is 200 lb/hr; other sizes are available

Approximate Dimensions & Weight

18' x 10' x 23' H; weighs 14,500 lbs

Approximate Energy Consumption

About 63 kWh per hour

Typical Installation Requirements
Electrical – 480 V, 3-phase, 125 A; Compressed air – 100 scfm and 90 psig at peak; Water – 5 gpm at 60 psig; Drain – 1-1/2" line; Hydraulic unit

Features & Options
An air compressor, waste carts, weighing scale, and hydraulic unit for the compactor are optional.

Stage of Commercialization
Early stage of commercialization

Permitting Status
The technology is approved in Texas with approvals pending in Illinois and New York. Applications have been filed in other states.

Approximate Costs
Approximate capital cost is about $385,000

Vendor Information
KC MediWaste, 4219 University Boulevard, Dallas, TX 75205; Ph. 214-528-8900; Fax 214-528-0467

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.*

DRY HEATING

Overview of the Technology
The Demolizer (Thermal Waste Technologies, Inc., formerly DOCC) is a desktop system for treating small amounts of sharps and soft "red bag" wastes at or near the point of generation. It is used in clinics, physicians' offices, dental offices, veterinary clinics, and medical departments.

How It Works
The operation of a Demolizer unit is as follows:

- *Waste loading*: Waste is collected in one-gallon containers for sharps or soft waste. When filled up to a safety line, the containers are closed and transferred to the unit. The operator must push a door-release button to open and close the lid of the unit.
- *Start of documentation*: The operator places a print-out/verification label into a slot on the processing unit.
- *Dry heat processing*: The process begins when the cycle-start button is pressed. There is an 18-minute warm-up. The waste then undergoes a dry heat disinfection cycle at 350°F (177°C) for 90 minutes.
- *Cooling*: The unit allows the waste to cool down for about 52 minutes to below 95°F (35°C). At the end of the 2-1/2 hour treatment cycle, the unit sends an audible signal and display message.
- *Final documentation*: The operator removes the print-out label and fills in the date, start and stop times, and operator's initials. Half of the print-out label is placed in a log book, the other is placed in the processed container.
- *Removal and disposal*: The processed container is removed and disposed with regular garbage.

Types of Waste Treated
The types of waste treated in the Demolizer include sharps and soft wastes (gauze, bandages, gloves, etc.) from patient care. Small amounts of liquid waste such as dressings soaked with blood or body fluids may also be processed, but not liquids in bulk quantities.

Volatile and semi-volatile organic compounds, chemotherapeutic wastes, mercury, other hazardous chemical wastes, radiological wastes, and human or animal body parts should *not* be treated in the Demolizer system. The manufacturer also prohibits the treatment of cultures and stocks, isolation waste, and bulk liquids in the Demolizer.

Emissions and Waste Residues
The conditions in the Demolizer treatment chamber do not produce any combustion byproducts. Emissions from the chamber are passed through a dual filtration system comprised of an activated carbon filter and a high-efficiency particulate air (HEPA) filter to remove odors and bacteria. Exhaust from the Demolizer was tested by Valley Medical Laboratory (Springfield, MD) for microbial spores. Results using *B. stearothermophilus* showed no detectable releases of bio-aerosols from the Demolizer to the surroundings.[3]

The treated waste is dry. Although the waste retains much of its physical appearance, the waste is sealed and disposed in the processed container. The sharps waste generally melts down into a disk-shape solid plastic with metal portions embedded inside. A test[4] of treated medical waste by Leberco Testing (Roselle Park, NJ) for 8 heavy metals showed no metal concentrations above EPA limits. Six of the 8 metals including lead, mercury, arsenic, and cadmium were below detection limits. The other two (barium and chromium) were well below regulatory levels.

Microbial Inactivation

The vendor commissioned a series of tests in the early 1990s. Microbiological tests[5] were conducted to show an 8 $\log_{10}$ kill of *B. subtilis*. Tests[6] also showed no growth of *Staphylococcus aureus, Candida albians, Mycobacterium fortuitum, Mycobacterium bovis*, and *Giardia sp*. Additional tests[7], all showing no growth, were done by AMA Laboratories using *E. coli, Pseudomonas aeruginosa*, and *Staphylococcus aureus*. Another test[8] showed inactivation of duck hepatitis B virus by the Demolizer.

Advantages and Disadvantages of the Technology

The Demolizer technology has the following advantages:

- The small device—weighing about 35 pounds—is somewhat portable although designed for operation in one location. As a countertop unit, it is used at or near the point of generation and eliminates the need for on-site storage or transport of infectious waste.
- It is accepted or approved as an alternative technology in 45 States.
- If proper precautions are taken to exclude hazardous material, the emissions from the Demolizer are insignificant. There are no liquid effluents.
- The technology is automated, easy to use, and requires a minute or so of labor time per cycle to operate. It employs microprocessor controls that have fail-safe features.
- Odors are eliminated by a dual filtration system. The operation is virtually noiseless.
- The waste containers have a heat-sensitive color-changing strip to identify treated and untreated containers. They remain sealed when disposed in the trash. The device includes a print-out for labeling and documentation.
- The system has a low capital cost and requires no major installation except for a standard 110v grounded outlet.

The disadvantages include the following:

- If hazardous chemicals are in the waste, these toxic contaminants may concentrate in the filter, escape into the air, or remain in the solid waste to contaminate the landfill.
- Since the unit is designed for small-volume generators, it cannot handle the waste for all of a hospital or large health care facility.
- The facility must purchase a single-use collection container for processing in the Demolizer. This consumable item accounts for a significant portion of the operating cost.
- Even though sharps waste is reduced in volume by about 75 percent, the container in which the waste is disposed of does not change size and there is an insignificant loss of weight of the treated material.
- The use of a disposable waste can adds mass to the waste that goes to the landfill.

Other Considerations

Below are some suggestions to consider when selecting this dry heat treatment system:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in a dry heat treatment system.
- The Demolizer is intended for small-volume generators but it could also be used in hospitals as a supplemental technology in conjunction with a larger non-incineration technology.
- The unit is designed such that if the process is interrupted after the temperature reaches 120°F, the unit cannot be opened. Instead, the unit resets and begins the full 90-minute cycle.
- Maintain records of biological indicator tests, treatment parameters, preventive maintenance activities, and periodic inspections.
- Provide worker training to include: a basic understanding of dry heat systems, standard operating procedures, occupational safety, recordkeeping, identifying waste that should not be treated in the unit, recognizing technical problems, and contingency plans (e.g., what to do in case of a spill or power outage).

DEMOLIZER[9]

Description

The Demolizer is offered by Thermal Waste Technologies or TWT. (See also above description.)

Capacity

Demolizer *Model 47*: up to one gallon per cycle (about 2-1/2 hours)

Approximate Dimensions & Weight

19-1/4" D x 13" W x 12-1/4" H, weighs 35 pounds

Installation Requirement

Electrical – 115 V, 750 W, 60 Hz

Features & Options

Thermal Waste Technologies also offers waste cans, labels, log books, a magnet for removing the waste cans, wall-mount bracket, and sharps container funnel.

Stage of Commercialization
Fully commercialized

Permitting Status
Accepted or approved in 45 states with site-specific or pending approvals in other states

Approximate Costs
Approximate capital cost of about $4,000; sharps waste and soft waste cans are about $4.25 each

Vendor Information
Thermal Waste Technologies, Inc., 19 Stony Hill Road, Bethel, CT 06801; Ph. 888-336-6549 or 203-778-2210; Fax 203-778-3114

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.*

NOTES

1. Data provided by KC Mediwaste.
2. Based on vendor brochures and technical data provided by KC MediWaste from 1997 to 2000, detailed written responses to technical questions, site evaluation of the technology installed at Mercy Health Center in Texas, and personal communications with Keith Cox.
3. "Bacterial Emission sample testing from the Demolizer System Medical Waste Treatment System," Valley Medical Laboratory, Springfield, MA, 1998.
4. "USEPA Regulatory Requirement Levels for Heavy Metal Concentration: Demolizer System Test Results," Leberco Testing, Inc., Roselle Park, NJ, August 2, 1993.
5. "Continuous Challenge/Validation Procedure for the Demolizer System" and test results, Leberco Testing, Inc., Roselle Park, NJ, December 9, 1994.
6. "Efficacy Testing of the Demolizer system medical waste treatment system," Leberco Testing, Inc., Roselle Park, NJ, November 10, 1992.
7. "Certificate of Analysis," AMA Laboratories, New City, NY, August 25, 1989.
8. "Efficacy of the Demolizer System on Hepadna Virus (Duck Hepatitis Virus), " tests conducted by Dr. Patricia Marion, Division of Infectious Diseases, Stanford University School of Medicine, November 9, 1992.
9. Based on brochures and technical data provided by DOCC, later TWT, from 1995 to November 1999, and personal communications with Jon Bricken.

Chapter 7

Medium- and High-Heat Thermal Technologies: Depolymerization, Pyrolysis, and Other Systems

Medium-heat thermal processes take place above 350°F and below 700°F. Two systems operating in this range have been referred to as reverse polymerization or thermal depolymerization. ("Polymerization" is the process of repeatedly combining a group of molecules to form a giant molecule called a polymer; rubber and plastics are examples of polymers. However, as applied to medium-heat processes, the term "depolymerization" is used loosely to mean the breakdown of complex molecules into smaller ones.)

High-heat thermal processes operate at temperatures above 700°F, generally ranging from around 1,000°F (540°C) to 15,000°F (8,300°C) or higher. High heat processes involve chemical and physical changes resulting in total destruction of the waste. A significant reduction in the mass and volume of the waste also occurs. Incineration is an example of a high-heat thermal process.

This chapter focuses on pyrolysis and advanced oxidation technologies as high-heat alternatives to incineration. The only fully commercialized system in this category is Bio-Oxidation, which uses pyrolysis and controlled oxidation in tandem. Some plasma systems, such as IET's Plasma Enhanced Melter and Vance IDS, are at the stage of initial commercialization. A few others have completed prototype or beta test models and are searching for a site for their first full-scale installation. Others are emerging technologies currently in the research and development phase. Many of these same systems are being designed to destroy not just medical waste, but also hazardous (RCRA) waste, expired pharmaceuticals, low-level radioactive waste, mixed waste, energetic (explosive) wastes, chemical and biological warfare agents, PCBs, controlled substances (illicit drugs), and other difficult waste streams.

DEPOLYMERIZATION

Overview of the Technology

For the purpose of describing this technology, the **Environmental Waste International (EWI) *MD-1000*** will be used as an example. The technology is relatively new and the description provided here is all based on material provided by EWI.[1]

The *MD-1000* directly applies high-energy microwaves to medical waste in a nitrogen atmosphere to break down the organic material. Unlike other microwave systems that heat the waste to near the boiling temperature of water, the *MD-1000* operates at temperatures high enough to cause chemical changes. The low-heat microwave units use between 2 to 6 magnetrons with outputs of around 1.2 kW each; the MD-1000 uses 14 magnetrons with a variable output of 3 kW each. As intense microwave energy is absorbed by the waste, the internal energy of the organic material increases to a point where chemical decomposition on the molecular level happens. Since heating with microwaves occurs primarily from the inside out, the inside of the waste material reaches high temperatures but the temperature of the chamber itself remains between 150 to 350°C (300 to 662°F). Burning can take place at the higher range of those temperatures but the nitrogen blanket forms an oxygen-depleting environment that inhibits combustion. At these temperatures, metals, ceramics, and glass are not chemically affected. The off-gases may contain hydrogen chloride which is neutralized in a scrubber, and simple hydrocarbons that are oxidized in a flare or low-flow combustor. Another option is to send the off-gases to a biofilter. A carbon residue remains. In the *MD-1000*, grinding takes place after the waste has been treated. The grinder is equipped with auto reverse and overload detection.

How It Works

The EWI operation is a three-stage operation involving (1) loading, weighing, and purging; (2) reverse polymerization using microwave energy; and (3) cooling and grinding. The complete cycle time is 50 to 80 minutes per load, depending on its mass. This corresponds to 2,700 lbs or 1,225 kg per day.

- *Waste loading, weighing, and purging*: Red bag waste on cardboard trays enters the first of three chambers. The chamber is sealed automatically and the waste is weighed. The air is then purged by replacing it with nitrogen.
- *Reverse polymerization*: The door to the next chamber opens and the waste is moved by a conveyor into the main treatment chamber. The outer door to the first chamber is then sealed. In the second chamber, in-

WHAT ARE BURN AND NON-BURN TECHNOLOGIES?

Burning refers to **combustion**, the rapid oxidation of a combustible material causing the generation of heat and fire, and the release of gaseous byproducts. If the combustible material contains carbon, a solid carbonaceous residue remains. Combustion takes place in an incinerator (from the Greek word for "burn to ashes"). In a complete combustion process, water and carbon dioxide are formed. However, in a typical medical waste incinerator, undesirable pollutants and products of incomplete combustion are also produced; these include particulate matter, carbon monoxide, acid gases, heavy metals, dioxins and furans, and other organic compounds.

It is commonly known that three things are needed for combustion to occur: a combustible material (or fuel), an oxidizer (e.g., air), and heat. But these alone are not necessarily sufficient. Three primary conditions must be met to initiate combustion: the temperature must be above the flash point, the vapor-air composition must fall between the flammable limits, and the temperature must equal or exceed the ignition point. The flash point is the lowest temperature at which a liquid or solid gives off sufficient vapor to form an ignitable mixture with air. The upper and lower flammability limits define the range within which the volume percent of the material in air can be ignited. The temperature at which a substance can begin to oxidize so rapidly that it produces heat and flame and becomes self-sustaining is called the ignition point. Ignition takes place at about 450°F (232°C) for gases from paper. This is why low-heat thermal processes do not involve combustion.

At high temperature, the level of oxygen in the treatment chamber determines whether combustion or pyrolysis dominates the process. If the waste is heated in the absence of air or in the presence of an inert gas, such as helium or argon, pyrolysis dominates. Unlike combustion, which is exothermic (generates heat), pyrolysis is endothermic (requires heat) and involves a different set of chemical reactions that produce different reaction products, such as methane and hydrogen. The resulting off-gas has a low- to medium-heat content and can be used as supplemental fuel. In actual practice, the process takes place, not in the complete absence of oxygen, but in an oxygen-depleted environment. Oxygen is still present among the molecules that comprise the waste material or as pockets of air trapped in the waste. Thus, carbon monoxide is also produced, along with small amounts of NOx, SOx, dioxins, and furans (at levels much lower than in combustion).

The solid residues from pyrolytic processes vary. In some cases, a mixture of inert carbon residue, elemental metals, and glassy material remains. Plasma pyrolysis generally produces a glassy slag or vitrified aggregate, and depending on the design, molten metals may be recovered. In any case, the residual waste is inert and unrecognizable, and its mass and volume are reduced by as much as 90 to 98 percent. Pathogens are not expected to survive under the very high temperatures. However, even with extremely high temperatures, the heat transfer characteristics in a plasma chamber may not necessarily mean uniform heating at elevated temperatures. Electrical resistance, induction heating, natural gas, and/or plasma energy are common ways of providing the high heat in a pyrolytic system. In plasma-based pyrolysis, which operates at much higher temperatures than incineration, glass and other inorganic material from the waste are melted and turned into a nonleachable vitrified slag. Another form of pyrolysis utilizes superheated steam ("steam detoxification") at temperatures involving steam-reforming reactions.

Non-burn technologies are those technologies where burning is not involved. Therefore, low-heat thermal systems, chemical-based technologies, irradiation, and biological systems are non-burn technologies. As defined above, technologies wherein the pyrolysis process dominates would also be non-burn even though they operate at temperatures at or above those of incinerators. Regardless of whether one accepts this definition or not, what is important are the environmental emissions and residues produced by the technology. Some new technologies, such as electromelter vitrification, operate as burn technologies in a manner similar to incinerators and emit pollutants characteristic of incinerators. In this chapter, an advanced oxidation technology—a burn technology—has been included because of unique features different from incinerators and its relatively low environmental emissions.

tense microwave energy is applied, causing molecular bonds to break.

- *Cooling and grinding*: The resulting carbonaceous residue is moved by the conveyor into the final chamber for cooling and grinding. A heavy-duty grinder reduces the size and the residue is moved to a cyclone receiver where it is deposited into plastic bags for landfill disposal.

Types of Waste Treated

EWI reports that the *MD-1000* can treat a wide range of infectious waste including biological and anatomical waste, needles, sharps, plastics, and glass.

Emissions and Waste Residues

The off-gas ranges from 30 to 120 cubic feet per minute during operation. The off-gas is passed through a neutralizing scrubber using sodium hydroxide. The gas can be burned in a low-flow thermal oxidizer (combustor). EWI conducted air emissions tests in 1994 from which they have computed estimates of maximum ground-level concentrations for various pollutants including simple hydrocarbons like butane, aromatic compounds like benzene and toluene, and criteria pollutants such as sulfur dioxide. The estimated concentrations were between one to six orders of magnitude below OSHA Threshold Limit Values. No dioxin tests were reported. Emission tests from pilot-scale units were also used to estimate full-scale emission rates. U.S. facilities would need emission tests at full-scale operation following EPA requirements.

In addition to air emissions, there is also wastewater from the scrubber. The solid waste residue is reportedly reduced up to about 80 percent in mass and volume. Results of chemical analysis of the carbonized residue samples for acceptability for landfill disposal in Ontario, Canada are available from the vendor. For the U.S., TCLP tests would be required.

Microbial Inactivation

Tests conducted for the manufacturer in 1997 by P.L. Seyfried of the University of Toronto Department of Microbiology showed a 6 $\log_{10}$ reduction for *B. stearothermophilus* spores.

Other Considerations

The *MD-1000* uses a nitrogen gas supply with a surge tank for purging the system. Consumables include cardboard trays, sodium hydroxide for the scrubber, and natural gas if a combustor if used to burn the off-gas. Computers monitor the process, control shutdown, and minimize operator intervention. A stainless steel cover contains the microwaves to minimize the potential for leakage. Energy use is about 85 kWh per hour. The main unit has a footprint of 9.3 ft x 32.4 ft. Around 19-28 m^2 of space is needed for auxiliary equipment. A height of 12 feet is required. The same technology is being developed for treatment of scrap tires. The technology is relatively new. Two medical waste treatment units are being installed in the United Kingdom. (Environmental Waste International, 283 Station Street, Ajax, Ontario, Canada L1S 1S3; 905-686-8689; Fax 905-428-8730; sales@ewmc.com, www.ewmc.com)

Other Technologies

Changing World Technologies (CWT) describes their technology as thermo-depolymerization, a patented process that purportedly converts organic waste into reusable products for commercial and industrial applications.[2] The process takes place in a completely enclosed circulating system that the vendors describe as emulating naturally occurring geological and geothermal processes in the earth's subduction zones. The technology combines water, temperature, and high pressure in a contained system. The system includes reactors, flash vessel, and oil separators. The TDP is being developed for food and agricultural waste processing to convert fats, bones, feathers, and other food wastes into diesel oil, gases, fertilizers, and specialty chemicals. The technology could convert heavy crude oil, coal, shale, tar sands, certain plastics, tires, and rubber into oils, fuels, gases, and carbons. Treatment of infectious waste is being considered. CWT owns Resource Recovery Corporation which developed the Thermo-Depolymerization and Chemical Reformer (TDP) for hazardous waste. The TDP is a joint venture with the Gas Research Institute (GRI). A 15-ton per day unit has been tested at the Philadelphia Naval Business Center. (Changing World Technologies, 460 Hempstead Avenue, West Hempstead, NY 11552; 516-486-0100; Fax 516-486-0460; cwt@changingworldtech.com)

PYROLYSIS-OXIDATION

Overview of the Technology

The Bio-Oxidizer, a commercialized technology, uses a two-step process. Firstly, the waste enters a pyrolysis chamber where it is heated from 200°F to 1,100°F (93°C-590°C). This causes organic solids and liquids to vaporize, leaving behind an inert ash including inorganic material such as glass and metal fragments. In the second step, the vapors are drawn by an induced draft fan from the pyrolysis chamber into a two-stage oxidation chamber operating at 1,800°F and 2,000°F (980°C-1090°C). Controlled amounts of oxygen are added in the oxidation chamber to complete the combustion process. With the addition of pollution control devices, the result is a rela-

tively clean exhaust stream (primarily water and carbon dioxide).

The Bio-Oxidizer system consists of an automatic waste loader, pyrolysis chamber, two-stage oxidizer, heat exchanger, scrubber, and computer controls. The automatic waste loader consists of a conveyor belt, bar code reader, weighing scale, and pneumatic lift.

How It Works

The operation of a Bio-Oxidizer is as follows:

- *Waste loading*: Waste is collected in boxes and bar codes are placed on the outside of the boxes. The boxes are then placed on a conveyor belt. Computer controls determine when a box can be fed into the pyrolysis chamber. The loader conveys the box past the bar code scanner, weighs the box, and determines if its dimensions are acceptable before lifting it up to the waste entry section which is an airlock above the pyrolysis chamber.
- *Pyrolysis*: Computer controls open the floor of the airlock allowing the box to fall onto a shelf in the pyrolysis chamber. Electric resistance heaters heat the box up to 1,100°F (590°C).
- *Two-stage oxidation*: Vapors from the pyrolysis chamber are mixed with controlled amounts of oxygen to complete the oxidation process at temperatures of 1,800 and 2,000°F (980°C-1090°C).
- *Cooling and heat recovery*: Hot exhaust gases from the two-stage oxidizer are cooled in a heat exchanger to produce hot water or steam that can be used by the health care facility.
- *Scrubbing and exhaust venting*: To remove any particulates and hydrogen chloride in the exhaust, the gas from the heat exchanger is passed through a wet scrubber and electrostatic precipitator. The exhaust vents through a low-temperature plastic or aluminum duct.
- *Waste collection and disposal*: The inert waste residue in the pyrolysis chamber collects on a tray beneath the chamber. The r2esidue is removed periodically and discarded as regular trash.

Types of Waste Treated

Because of its high temperatures, the Bio-Oxidizer can handle all wastes normally treated in an incinerator. These include cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. In addition, the technology can handle plastics, blood and body fluids, pathological waste, animal waste, and dialysis waste. (Technically, this technology is capable of destroying bulk chemotherapeutic waste, pharmaceutical waste, hazardous waste, and controlled substances but treating these waste streams in a health care facility may be prohibited by regulations or require special permits.)

Radiological wastes and waste contaminated with mercury should *not* be treated in the Bio-Oxidizer.

Emissions and Waste Residues

There are virtually no perceptible odors around the Bio-Oxidizer system, in part because of the negative pressure in the unit and the pollution control devices cleaning the exhaust stream.

Tests[3] conducted by Ramcon Environmental Corporation (Memphis, TN) show that air emissions from the Bio-Oxidizer were one to three orders of magnitude lower than the new EPA emission limits for a new incinerator of about the same size; dioxins and furans were three orders of magnitude below the EPA limits. In another test at a Bermuda facility, dioxin levels were an order of magnitude below the EPA limit. The exhaust gas — primarily of carbon dioxide and water — is at about 110°F (43°C), much like the exhaust from a clothes dryer.

There is no liquid effluent from the Bio-Oxidizer. Water used in the wet scrubber is recirculated. To reduce build-up of salt and suspended solids, some water is periodically sent to an evaporator tank where the water is vaporized and the solids are mixed with the residue from the pyrolysis chamber.

The treated waste is dry, inert, and essentially sterile. It has consistently passed EPA's toxicity characteristic leachate procedure (TCLP) test. Mass reduction can be as high as 95 percent, and volume reduction may even be higher.

Microbial Inactivation

Because of the very high temperatures, the waste residue is expected to be inert and practically sterile.

Advantages and Disadvantages of the Technology

The Bio-Oxidizer has the following advantages:

- The Bio-Oxidizer process results in total destruction of medical waste with very low emission levels compared to those of incinerators. It does not require a stack; the exhaust gas vents through a low-temperature duct.
- It can treat the wide range of medical waste (except for radiological waste and mercury).
- There are no liquid effluents. The waste residue is inert, unrecognizable, and essentially sterile and can be disposed in a regular landfill. Mass and volume reductions of 95 percent or greater are achieved.

- The Bio-Oxidizer recovers up to 80 percent of the heat in the form of hot water or steam.
- There are almost no odors and very little noise during operation. Despite high temperatures in the pyrolysis chamber and oxidizer, the surfaces of the unit are at about room temperature.
- A bar code system provides documentation that can be stored electronically or printed out by the computer.
- The system is fully automated, requiring only a few minutes of operator time per hour. The loader automatically loads boxes as needed.
- The conveyor system is ergonomically designed to minimize lifting.

The disadvantages include the following:

- Despite lower emissions than conventional medical waste incinerators, the Bio-Oxidizer still emits dioxin, which has been linked to serious health problems including cancer.
- The installed capital cost of the Bio-Oxidizer *M-100* model is very high in relation to its throughput capacity. The technology may not be cost-effective for small hospitals and health care facilities.
- The required space and footprint of the Bio-Oxidizer is large compared to other technologies of the same capacity.
- The facility has to purchase boxes of the correct dimensions to fit the waste entry section.

Other Considerations

Below are some suggestions to consider when selecting the pyrolysis-oxidation treatment system:

- The operator should follow the daily preventive maintenance schedule that includes cleaning the conveyor system, emptying the waste residue tray, and checking sensors.
- Major maintenance items include: conveyor belts, heating elements, fans, and components of the scrubber and electrostatic precipitator.
- Because of the high capital cost, facilities might consider an arrangement whereby Bio-Oxidizer owns and operates the unit at the facility and is allowed to treat waste from small generators in the area.
- The *Model 100* has been installed in various facilities; *Model 1000* is under development.
- Maintain records of treatment parameters, preventive maintenance activities, and periodic inspections.
- Provide worker training to include: a basic understanding of pyrolysis systems, standard operating procedures, occupational safety, record-keeping, identifying waste that should not be treated in the unit, recognizing technical problems, and contingency plans (e.g., what to do in case of a spill or power outage).

Bio-Oxidizer[4]

Description
The Bio-Oxidizer is a trademark of Bio-Oxidation Services, a subsidiary of Harsco Corporation. Oxidation Technologies assists health care facilities in installing and operating the Bio-Oxidizer. The principals of Oxidation Technologies have been involved in developing, installing, and operating the Bio-Oxidizer and large-scale steam treatment units for 10 years. (See description above.)

Models-Capacities
Model #100 – 100 to 125 lbs/hr; *Model #1000* – about 1,000 to 1,500 lbs/hr

Approximate Dimensions
Model #100: 42' L x 12' W x 12' H

Approximate Energy Consumption
Model #100 uses about 0.6-1.2 kWh per pound of waste treated; *Model #1000*, about 0.1 kWh per pound. Approximately 80 percent of the heat is recovered as hot water or steam.

Typical Installation Requirements
Electrical – 480 V, 3-phase; Water – 5 to 10 gpm when needed; Compressed air – 100 psig; Vent – 6" to 12" duct

Features & Options
Instead of purchasing the equipment, Oxidation Technologies also offers health care facilities a full service contract, a turnkey operation wherein the facility pays a cost-per-pound fee that includes operation, service, and maintenance by Bio-Oxidation. They also offer design, installation, permitting services, training, occupational health and safety programs, and other services.

Stage of Commercialization
Commercialized

Permitting Status
The technology is approved in about seven states and in Bermuda.

Approximate Costs
Approximate installed capital cost: *Model #100* - $1.6 million; *Model #1000* - $3.3 million; full service contract depends on model, volume of waste, and other factors.

Vendor Information
Oxidation Technologies, Inc., 613 Third Street, Annapolis, MD 21403; Ph. 410-990-9430; Fax 410-990-9431; www.oxid-tech.com; barrj@oxid-tech.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.*

PLASMA-BASED PYROLYSIS SYSTEMS

Overview of the Technology

Not to be confused with the fluid part of blood, the term *plasma* as used in medical waste treatment is a physical state of matter comprised of ionized particles such as electrons and charged ions. In the plasma state, the ionized gas can conduct electric current, but due to its high resistance, the electric energy is converted to heat producing temperatures ranging from 3,000 (1650°C) to as high as 21,000°F (11,600°C). Most systems use a plasma-arc torch to generate the plasma energy. In a plasma torch, an arc is established between two electrodes. A carrier gas, which may be inert or have some heating value, passes between the electrodes and transfers the energy to the waste material. In a non-transferred system, the anode and cathode are both part of the plasma torch. Another design is to use a DC (direct current) plasma arc, wherein the arc forms between a graphite electrode directly to the metal in a molten bath formed from the waste in the treatment chamber.

This section describes several plasma technologies. Some of these technologies are in the development phase and may take several years before becoming commercialized; others are in their initial stage of commercialization.

NOTE: Plasma pyrolysis is a relatively new technology that has very little track record. While some specific pyrolysis technologies show promise, others have not achieved performance and emission levels claimed by manufacturers and others have not worked at all. Facilities considering a plasma system should carefully evaluate the plasma technology's performance and emission levels under realistic operating conditions. HCWH does not endorse any specific technology or company.

How the Process Works

In general, a plasma system works as follows:

- *Waste loading*: The waste is introduced through a feed handling section which may or may not include an internal shredder, ram, or auger.
- *Plasma pyrolysis*: The waste is then exposed to very high temperatures produced by a plasma-arc torch in the pyrolysis chamber operating at around 3,000°F (1,650°C). At these temperatures, the waste is destroyed, forming a product gas, at times referred to as syn gas, with a heating value that may be as much as 300 BTUs/scf.
- *Energy recovery*: Energy can be recovered from the product gas by using it as supplemental fuel to produce steam or hot water or in co-generation. In some cases, the gases are simply burned in a flare. In the future, the product gases that are rich in hydrogen or methane could be used in conjunction with fuel cells to produce clean electricity.
- *Waste residue collection*: The solid residue from plasma technologies may include carbon black, vitrified glassy aggregates, and metallic residues. In some designs, the metals can be recovered; some of the metals may also be encapsulated in the glassy rocks.

Types of Waste Treated

Because of their extremely high temperatures, plasma-based technologies are, in principle, capable of destroying a wide range of wastes including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. In addition, the technology can handle plastics, blood and body fluids, pathological waste, animal waste, residual chemotherapeutic wastes, and dialysis waste.

Many plasma technologies can also destroy bulk chemotherapy waste, many hazardous substances, spent solvents and chemicals (e.g., formaldehyde, glutaraldehyde, xylene, isopropanol, etc.), expired pharmaceuticals, low-level radioactive waste, etc. (One exception is mercury, which many plasma systems are not able to handle.) Therefore, from a technical standpoint, plasma systems can treat the same types of waste as an incinerator. However, treating some of these waste streams at a given site may require special permits or may be prohibited by regulations. Different plasma technology designs have varying emission characteristics and may be better suited for certain types of waste than others.

Emissions and Waste Residues

Plasma-based technologies can handle the same types of waste as an incinerator but have emissions that are gen-

erally lower than those from traditional incinerators. Some pollutants, including dioxins and furans, may be one to three orders of magnitude below the EPA emission limits for new incinerators of the same size. However, some studies have shown that tars produced by the pyrolysis of PVC plastics under low-temperature pyrolysis (500°C) and reduced oxygen have significant dioxin/furan concentrations[5] and that high-temperature pyrolysis of PVC produces other toxic substances[6]. Facilities should confirm the environmental emission levels by examining stack test results conducted by independent laboratories. In cases where the product gases are simply burned in a flare, the combustion byproducts from flaring should be taken into account in determining the total emissions.

Plasma systems result in dramatic reductions in waste volume and mass. Overall waste volume is reduced by around 95 percent or more and mass is reduced by about 80 to 90 percent.

The very high temperatures in a plasma chamber cause inorganic constituents in the waste to melt. Glass material turns into a glassy slag that binds and encapsulates many heavy metals, thereby preventing them from leaching into the environment. Other metals may form alloys. EPA's toxicity characteristic leachate procedure (TCLP) conducted by independent labs are used to verify that the residual materials are inert and non-leachable and can be disposed of in a sanitary landfill. Some vendors have advocated recycling the inert glassy slag as building material and road filler but the idea has yet to be thoroughly tested by independent research.

Microbial Inactivation

Due to the high temperatures, the waste residues are expected to be sterile for all practical purposes.

Advantages and Disadvantages of the Technology

Plasma pyrolysis technology has the following advantages:

- The technology results in total destruction of the medical waste with low emission levels (compared to those of incineration).
- Plasma systems can handle the widest range of medical waste streams except for mercury.
- Waste mass and volume are drastically reduced.
- Plasma-based technologies generally produce a product gas with a low to medium heating value. Energy can be recovered from the gas in various ways.
- The waste residue is non-leachable, inert, and practically sterile. In some designs, metals may be recovered.
- Well-designed plasma systems are computer-controlled and well automated.
- Plasma technologies are suited for large-scale, continuous operations at a regional treatment center.

The disadvantages include the following:

- Despite many plasma systems having lower emissions than traditional medical waste incinerators, plasma technologies may still emit dioxin, which has been linked to serious health problems, including cancer. Poorly designed systems or pyrolysis units that operate at low temperatures may generate significant amounts of dioxins/furans as well as other toxic substances in the residues.
- While some prototypes and full-scale models have operated successfully at manufacturers' or test facilities for periods of time, the plasma systems do not have much of an operating track record at a health care facility or regional treatment center.
- Because plasma pyrolysis is a complex but relatively new technology, some designs may prove to be unreliable and subject to frequent equipment failures.
- Due to the heterogeneity of the medical waste feed, the stability of the plasma system may be a problem if the technology is not well-designed and does not have good process control.
- Plasma systems have a high capital cost and significant siting and installation requirements.
- Operating costs, including electricity and consumables (plasma torches have a limited life span), may be significant.
- Because of the high energy consumption with plasma systems, facilities should consider total environmental impact to include not just emissions on-site (including pollutants from any co-generation or flaring of the off-gases) but also environmental emissions associated with high electrical usage, i.e., off-site emissions contributed by electric power generating stations.
- Some plasma-arc torch designs may affect power quality in a hospital and cause flicker.
- Many (but not all) of the plasma technologies are designed for large-scale operations and may not be suitable for on-site use at a hospital.

Other Considerations

Below are some ideas to consider when selecting plasma-based treatment systems:

- Being a new technology, all plasma systems should be carefully evaluated. Performance and emission tests

should be conducted under realistic operating conditions.

- Many units are still in the development phase and some technologies may not be fully commercialized yet. Some vendors of plasma technologies may be willing to offer large discounts in exchange for being able to demonstrate their technology at a health care facility.
- Since all of these technologies are new, a site visit to a user's facility is essential in order to evaluate the technology while in operation.
- A program to inform and discuss this technology with the local community and staff is important since the technology is not well-known nor understood.
- Make sure that an effective waste segregation plan is in place to keep mercury from being introduced into the system.
- To be more cost-effective and lessen the problem of heat stresses from frequent start-ups, the plasma systems are better suited for continuous operation.
- Vendors often discuss the possibility of recycling the carbon black (as a tire filler) or glassy waste residues (as roadbed or construction aggregate). A technical and economic feasibility study should be conducted by an independent research group and, if the concept is found to be beneficial, an implementation plan should be developed.
- Flaring the off-gas adds to environmental pollution. The design should incorporate a heat recovery process (such as a heat exchanger to obtain steam or hot water) using the product gas.
- Maintain records of treatment parameters, preventive maintenance activities, and periodic inspections.
- Provide worker training to include: a basic understanding of pyrolysis systems, standard operating procedures, occupational safety, recordkeeping, identifying waste that should not be treated in the unit, recognizing technical problems, and contingency plans (e.g., what to do in case of a spill or power outage).

Descriptions of Plasma-Based Systems

Daystar Technologies[7] is a plasma-based technology that uses two chambers: in the first chamber, heat from a compact plasma torch maintains an operating temperature of over 3,000°F (1,650°C) to pyrolyze the medical waste; gases from the first chamber are then thermally oxidized in a second chamber. Liquid slag from the pyrolysis process is cooled and solidified into a gravel-like non-leaching residue. Gases from the second chamber are passed through a heat exchanger to obtain hot water, then filtered to remove particulates, scrubbed, and vented into the atmosphere. The Daystar system is a top-loading unit designed in 200 pound-per-hour (90 kg/hr) modular units with about 80-90 percent heat recovery. It handles a wide range of medical waste. The system has been tested at a hospital in central Tokyo. Construction of a unit in Iowa was discontinued, apparently for financial reasons. A new site is being sought. (Prometron Technics Corporation, Nibancho-on Building 47 11-6, Nibancho, Chiyoda-ku, Tokyo 102, Japan; Ph. 81-3-5275-2411; Fax 81-3-5275-2415; or M. Funai of Masuda, Funai, Eifert & Mitchell, One East Wacker Drive, Chicago, IL 60601)

The **EPI/Svedala**[8] (Electro-Pyrolysis, Inc./Svedala Industries Inc. Pyro Systems) graphite-arc technology uses a DC arc furnace to destroy medical waste. The arc temperatures are in the range of 9,000-10,000°F (4,980-5,540°C). The furnace uses a graphite crucible containing a molten bath of slag and metal that is heated by electrical resistance as well as radiant energy from the arc. A unique feature of this technology is the use of concentric electrodes: during startup, an arc strikes between an inner and outer electrode heating the waste until it is melted; once there is enough molten metal, the inner electrode is raised out of operation and the arc forms between the outer electrode and the metal bath. The length of the arc can be changed by raising or lowering the remaining electrode. The furnace can be operated in an oxidizing (combustion) or reducing (pyrolysis) atmosphere. In an oxidizing atmosphere, combustion gases are formed. A reducing atmosphere allows greater control of the temperature and produces a low to medium-energy gas that can be used as supplemental boiler fuel. Metals in the waste are collected in the molten metal bath and can be recovered intermittently through a metal tap. Other materials collect in the slag which is removed continuously through a heated slag tap and cooled to form a vitrified product. The Svedala/EPI system has graphite electrodes, refractory-line steel shell with a graphite crucible, slag and metal taps, water-cooling system, gas outlet with pollution abatement devices, and controls. The unit requires between 112 to 2250 kW power and water for cooling. Design capacity is about 750 pounds per hour (340 kg/hr). The technology has been tested with surrogate medical waste in a controlled reducing atmosphere. (Electro-Pyrolysis, Inc., 996 Old Eagle School Road, Wayne, PA 19087, Ph. 610-687-9070, Fax 610-964-8570; Svedala Industries, Inc., 350 Railroad Street, Danville, PA 17821-2046, Ph. 570-275-3050, Fax 570-275-6789)

HI Disposal Systems[9] has been working on the installation of a Plasma-Based Pyrolysis-Vitrification (PBPV) technology that uses plasma to heat medical waste and

controlled amounts of steam in a processing chamber at about 3,000°F (1,650°C). The technology uses a 2 MW plasma arc torch. The waste is converted into a non-leachable, glassy aggregate and a low-BTU gas (mostly hydrogen, carbon monoxide, nitrogen, carbon dioxide, methane, and water vapor) with a heating value of about 300 BTU/scf. The HI Disposal system is comprised of a feed handling section, plasma heating, waste processing chamber, product gas treatment section (quenching and scrubbing), wastewater treatment section, glass handling system, gas analyzer, regenerative thermal oxidizer/energy recovery system, and controls. The system has been designed for a capacity of 3,000 pounds per hour (1,360 kg/hr) or a maximum of 36 tons per day (33 Mg/day). The product gases can be used to generate electricity in a co-generation facility or to produce methanol. The glassy rock, which passes EPA's TCLP tests, can be recycled as construction or roadbed material. HI Disposal estimates getting 150 pounds of glassy aggregate for every 2,000 pounds of waste. The technology is also being planned for the destruction of hazardous waste. HI Disposal Systems has acquired space and permits in Indianapolis, Indiana for a regional waste disposal facility. The technology was developed by Plasma Energy Applied Technology (PEAT) in Huntsville, AL. (HI Disposal Systems, P.O. Box 1724, Indianapolis, IN 46206-1724; Ph. 317-693-1265 or 800-995-1265; Fax 317-262-1265; www.hawkinsindustries.com; info@hicompanies.com)

Integrated Environmental Technologies, LLC,[10] or IET has developed the Plasma Enhanced Melter (PEM) to transform waste into highly stable glass-like residues, recoverable metals, and a hydrogen-enriched gas. The technology is unique in that it combines three processes: plasma arc using multiple graphite electrodes, joule (resistance) heating using glass melter technology, and superheated steam. This combination results in a stable and highly controllable treatment system. The plasma operates at temperatures from 3,000° to 10,000°C (5,400 to 18,000°F) in an oxygen-free environment with the presence of superheated steam ensuring that pyrolysis and steam reforming reactions dominate. A high-efficiency scrubber is used to remove volatile metals and other pollutants from the hydrogen-rich product gas (100 BTU/scf or more), a portion of which may be recycled to provide power to the PEM and another portion used to generate electricity. Metals in the waste are recovered. The glassy aggregate is also recovered and may be recycled as road building, blasting grit, or construction material. Volume reductions are up to 98 percent depending on how the process is run and the composition of the waste. IET is interested in treating radioactive, hazardous, industrial, municipal, tire, incinerator ash, and medical waste streams. When destroying incinerator ash, IET was not able to detect dioxins or furans; other tests demonstrated a greater than 99.9999 percent (six 9's) destruction efficiency for naphthalene and chlorobenzene. IET's Process Test Facility and Technology Center is in Richland, Washington. The first PEM unit (1/2 ton per day) has run for over 15,000 hours since 1997. A 10-ton per day commercial prototype has been operational since July 1999. A one-ton per day unit has also been constructed. There are plans to install the first medical waste commercial treatment system in Hawaii. (Integrated Environmental Technologies LLC, 1535 Butler Loop, Richland, WA 99352; Ph. 509-946-1901; Fax 509-946-1819; www.inentec.com; inentec1@inentec.com)

MSE Technology Applications, Inc.[11] has developed a plasma technology system. The plasma arc torch creates a molten bath in a crucible with temperatures of 2,500° to 3,000°F (1,370° to 1,650°C). Waste is gradually fed into the crucible. To operate the process in an oxidizing atmosphere, oxygen is added to the chamber to ensure full oxidation; under these conditions combustion, not pyrolysis, is the dominant process. When the capacity of the crucible is reached, the molten slag is removed and transferred into a slag collection system where it solidifies into a glassy aggregate. Gases are drawn into a secondary chamber where a natural gas-fired afterburner maintains temperatures greater than 1,800°F (982°C) to achieve complete combustion of the residual organic compounds. A pollution control system removes pollutant emissions. Feed rates of up to 350 pounds per hour (159 kg/hr) are possible. The system is being developed for treatment of hazardous, industrial, ordnance, as well as medical waste. MSE Technology Applications has prototype units in Butte, Montana and is developing a portable unit. (MSE Technology Applications, Inc., 200 Technology Way, P.O. Box 4078, Butte, MT; Ph. 406-494-7100; Fax 406-494-7230; www.mseta.com; mseta@buttenet.com)

Plasma Pyrolysis Systems, Inc.[12] is developing a system for treatment of medical waste. The process uses a plasma torch in a reactor chamber to generate temperatures up to several thousand degrees. In one design, medical waste is placed in cardboard containers (12" x 12" x 24") and fed into a loading chamber where a piston pushes them into the reactor chamber. Residual solids are collected in a ceramic pot while off-gas is rapidly quenched and sent to a post-processing unit comprised of an alkali neutralizer and two-stage scrubber to remove acid gases (especially HCl) and particulates. The scrubbing process removes non-combustible material, while combustible waste combines with oxygen to form water vapor, carbon monoxide, carbon dioxide, and other simple compounds. The off-gas may be fed to a boiler as supplemental fuel. A computer controls the highly automated process. Residual solids are precipitated out and collected in the pot. The whole

system handles about 6 lbs/min and can fit in two trailers or side-by-side containers, one to house the reactor and the other for the post-processing unit. Alternatively, the system can be placed in a single, transportable, 53-ft trailer. Other designs are being developed for the treatment of used oils and hydraulic fluids, paints, pharmaceutical waste, sludge, and industrial waste. (Plasma Pyrolysis Systems, Inc., Box 158, Stuyvesant Falls, NY 12174; Ph. 518-828-4684; Fax 518-822-0132)

The **Startech Plasma Waste Converter**[13] is a destruction technology being developed for treating hazardous and nonhazardous waste such as pharmaceuticals, explosives, paints, solvents, PCBs, confiscated drugs, filters, oils, and medical waste. The waste is treated in a plasma zone heated by a plasma torch to temperatures between 6,000° and 16,000°F (3,315° and 8,870°C). Metals, glass, and silica in dirt are heated into a molten mass, while organic materials are gasified to form a clean synthetic gas (called "Plasma Converted Gas" by Startech) that can be used as fuel, chemical feedstock, or for other purposes. The gas is cleaned in a series of gas cleaning operations comprised of a high temperature cyclone separator to remove particulates, a spray dryer to quench the gas to about 150°C, and then a packed bed adsorber. The gas is collected for reuse. If necessary, a device to remove traces of nitrogen oxides can also be added. The metals can be recovered and the molten silicates can be used as aggregate fill or abrasives. A 300-to-1 volume reduction is claimed by the vendor. Startech has also been looking into the destruction of chemical weapons stockpiles. The results of demonstration tests of their Plasma Waste Converter under the Assembled Chemical Weapons Assessment Program of the Department of Defense raised issues related to hazardous byproducts, difficult process control, lack of maturity of process configuration, and problems in reliability, availability, and maintenability[14]. (Startech Environmental Corporation, 79 Old Ridgefield Road, Wilton, CT 06897; Ph. 203-762-2499; Fax 203-761-0839; www.startech.net; startech@netaxis.com)

The **Vance IDS**[15] uses several plasma torches in multiple chambers to break down medical waste. Unlike many of the other plasma technologies, the IDS is specifically designed as an on-site treatment technology for a hospital or medical center. An electrical current through the arc torches is used to heat waste to high temperatures in a low-pressure inert atmosphere. Recent design changes no longer require storage of inert gas. The waste is broken down into carbon black, elemental metals, and silica residue. Gases from the process are passed through an off-gas treatment system. IDS believes that the carbon black can be reclaimed and used as feedstock to the tire industry, as an inert filler, and other common industrial products. They claim that volume and mass reductions as high as 97-98 percent are possible. The system has a hopper, shredder, two processing chambers, rollers, heat recovery system, inert gas generation system, residue collection, scrubbers, PLC controls with communications, and safety and shutdown systems. In recent years, IDS has made several design changes to their prototype to improve stability, energy efficiency, gas handling and emission reduction, and engineering performance. Despite several delays, the first unit is expected to be installed in 2001 at a hospital in Florida. The technology is marketed for medical waste treatment by Bio Arc. (Bio Arc, 11440 66th Street N, Largo, FL 33773; Ph. 727-548-0640; Fax 727-549-8097)

IET's Plasma Enhanced Melter[16]

Description
(See above)

Capacities
One-half ton per day; One-two tons per day; Four tons per day; and 10 tons per day; other capacities are possible

Approximate Dimensions
The four-ton per day unit is about 15' x 20' x 14' H.

Approximate Energy Consumption
About 0.6 kWh per pound during plasma arc operations; power demand during idling is 10 kW

Features & Options
The system is highly automated. IET has assembled a technical team to provide technical services, including specialists from Battelle Pacific Northwest National Labs and MIT.

Stage of Commercialization
Initial stage of commercialization

Approximate Costs
A small unit including generator (to recover energy from the gas) is about $800,000.

Vendor Information
Integrated Environmental Technologies LLC, 1535 Butler Loop, Richland, WA 99352; Ph. 509-946-1901; Fax 509-946-1819;www.inentec.com; inentec1@inentec.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.*

VANCE IDS[17]

Description
(See above)

Capacity
Standard model: 400 lbs/hr

Approximate Dimensions & Weight
8' W x 12' L x 7' H (height depends on loading mechanism used); weights 18,000 lbs

Approximate Energy Consumption
Estimated at 0.365 kWh per pound of waste treated

Typical Installation Requirements
Electrical – 480 V, 600 A, 3-phase; Water – 1 gpm; Drain – 3"

Stage of Commercialization
Very initial stage of commercialization

Permitting Status
The Vance IDS has initial approvals from Florida, Louisiana, and several other states.

Approximate Costs
Approximate capital cost of $750,000, not including site preparation and installation. Operating costs would include utilities and consumables.

Vendor Information
Bio Arc, 11440 66th Street N, Largo, FL 33773 or Vance IDS, P.O. Box 98, Pinellas Park, FL 33780; Ph. 727-548-0640 or 727-548-9572; Fax 727-549-8097

*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.*

INDUCTION-BASED PYROLYSIS

The concept of induction heating dates back to experiments in the 1830s showing that electric currents can be induced in an electrical conductor if it is coupled with a coil carrying an alternating current. For example, passing an alternating current through a copper wire wrapped around a metal tube generates a varying magnetic field which, in turn, creates eddy currents in the tube. With each voltage drop, electrical energy is converted into heat. At high currents, enough heat is generated for melting and forging operations as well as possible treatment of medical waste.

Vanish Technologies[18] had been developing an induction-heated technology for medical waste destruction. Medical waste is fed through a charge hopper. Air is purged from the system and an electrical induction coil surrounding a tube furnace heats the walls of the tube from 1,400°F to as high as 1,800°F (982°C). The waste is conveyed through the tube using an internal rotating screw or auger. By purging the tube with nitrogen or an inert gas, the induction-heated tube operates under pyrolysis conditions. The waste is reduced to an inert carbon residue. Gas generated by the decomposition of the waste is cleaned in a gas cleaning system and can be used as replacement or supplemental fuel for the hospital boilers. The carbon residue can be sent to a landfill. The Vanish system is composed of automatic feed, induction tube, discharge chamber for the solid residue, gas cleaning system, and off-gas storage. The Vanish system has a capacity of about 280 pounds per hour (127 kg/hr). Greater than 90 percent volume and 80 percent mass reductions may be achieved. After some demonstrations by The Carbon Group and pilot tests in the late 1990s, research and development work on the Vanish system has been sporadic. (Vanish Technologies, c/o Joanne Jaeger, Levine Fricke Recon, 5 Johnson Drive, Raritan, NJ 08869; Ph. 908-526-1000 ext. 450; Fax 908-526-0923; Joanne.jaeger@lfr.com)

ADVANCED THERMAL OXIDATION

Overview of the Technology

This section looks specifically at **NCE Corporation**'s advanced thermal oxidation technology.[19] Unlike the other high heat technologies mentioned above, which operate under pyrolytic conditions, advanced thermal oxidation is a combustion process (it has been called an "advanced incinerator"). However, unlike traditional dual-chamber incineration where waste is burned inside a primary chamber in a "starved air" mode, this technology uses an oxygen-rich fast-burn process.

Advanced oxidation technology differs from traditional incineration in at least three basic ways: (1) the waste is shredded internally into small particles before being burned; (2) the shredded particles are injected at high speed into the primary chamber where they are carried by a rapidly swirling, oxygen-rich hot vortex generated by multiple gas burner jets located strategically inside the chamber; and (3) combustion gases are rapidly quenched using liquid mist injectors. In addition, the residence times are longer in the primary and secondary chambers—up to 3.5 seconds in each chamber, compared to a 1-second residence time in the secondary chamber of many traditional incinerators. Moreover, the secondary chamber of the advanced oxidation technology operates

at higher temperatures than in traditional incinerators. The entire process is computer controlled. These design differences are significant in that they allow a more efficient and complete combustion than traditional incinerators and minimize the temperature range at which dioxins and furans are formed.

Description

NCE Corporation's **TurboClean** is an advanced thermal oxidation system for medical waste using a patented "flash-burn," oxygen-rich, high-temperature combustion process. Medical waste is shredded using a four-shaft shredder assembly with an auger and sizing screen to provide good feed control. Shredded particles of about half a pound or less are injected one at a time with air into a high-speed vortex in a primary chamber operating between 1850° to 2,000°F (1,010° to 1,093°C). Thermal oxidation is rapid and efficient under these conditions. Ash is removed at the bottom, while the combustion gases flow into a secondary chamber at 2,000 to 2,150°F (1,093° to 1,177°C) to complete the combustion process. To withstand the high temperatures, the chambers use a lightweight, space-age product used for space shuttle reentry. The hot combustion gases are quenched rapidly to 325°F in a cooling chamber and liquid mist injectors. The gas is cleaned in packed bed absorbers and a venturi section to remove particulates before exiting the exhaust duct at a temperature of about 150°F.

The TurboClean is composed of loader, shredder, material injection system, primary and secondary chambers, cooling chamber, a 30 HP turbo fan, liquid mist injectors, and liquid filtration system. Volume and mass reductions as much as 97 percent or more may be achieved. The standard throughput rate is 200 lbs/hr, but higher capacity units could be designed. It is highly automated. A data acquisition system monitors sensors throughout the process. NCE offers five half-day training sessions for operators; no special skills or knowledge is required. NCE also offers a full service contract.

The TurboClean can handle all wastes normally treated in an incinerator including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes, soft wastes, blood and body fluids, pathological waste, animal waste, chemotherapeutic wastes, and dialysis waste. However, aerosol cans, machine oils, batteries, large metal objects, radioactive material, x-ray film, lead containers, mercury, and other materials containing toxic metals should *not* be treated in the TurboClean. Emission tests have been conducted and indicate that the TurboClean can meet the EPA standards for new incinerators. NCE is seeking approval as an alternative technology in Texas and other states. Prototype units had been tested at a health center in Waco, Texas and at the manufacturer's facility in Carrollton, Texas. The technology is also being tested for destruction of illegal drugs, contraband, and coded material. The 200-lb/hr unit costs about $776,000 and is in the very initial stage of commercialization. (NCE Concepts, 2150 Chennault, Carrollton, TX 75006; Ph. 214-991-4090; Fax 214-991-9334)

OTHERS

NOTE: The information below is based solely on limited vendor information.

The **Anara Group Ltd.**[20] has been developing a Laser Waste Destruction (LWD) system for processing both liquid and solid wastes since 1995. The technology is intended for a regional treatment center. The plasma is formed as a high-energy laser bombards the waste material. The reaction chamber operates around 6,000 to 10,000°F. It produces a hard slag residue that reportedly passes TCLP tests and may be used as road-bed aggregate and in bricks, tiles, and other applications. The technology could also recover metals and carbon black that may be recycled for use in the tire industry. The exhaust gas passes a particle trap, baghouse filter, and water bath. Capacities range from five to 100 tons per day. The design incorporates co-generation technology. The unit has been tested to treat hazardous solvents, shredded tires, PCBs, waste oils, diesel fuel, and municipal solid waste. Capital cost including training range from about $8 million to $25 million depending on size. (Anara Group Limited, Wells Fargo Financial Center, 3770 Howard Hughes Parkway 195, Las Vegas, NV 89109; Ph. 702-220-8405; Fax 800-863-8541; www.anara.com)

Balboa Pacific Corporation[21] has developed the BAL-PAC Pyrolytic Converter System for both solid and liquid hazardous waste as well as non-hazardous waste. Waste material is fed through a series of valves and gates synchronized so as to limit oxygen. Waste is conveyed into a pyrolytic chamber by a rotary screw. The chamber is heated to temperatures from 1,200 to 1,800°F by natural gas burned at a rate of about 500 cubic feet per minute. The gases liberated by the pyrolysis are drawn into a natural gas-fired "closed coupled thermal oxidizer" where they are ignited at about 1,600 to 2,250°F for two seconds. The hot gas is sent to a heat recovery boiler and exits through a wet scrubber and carbon bed at about 150°F. Inert char residue is expelled to a discard conveyor. The system can be designed to include pre-shredding and screw conveying of the waste feed. The BAL-PAC unit has been tested on municipal waste, shredded tires, spent catalyst, and PCB-contami-

nated oils. PCB destruction efficiencies of 99.99998 percent for liquid feed and 99.969 percent for solid feed were calculated.[22] Limited emission tests on municipal waste feed are available for cadmium, lead, carbon monoxide, and NOx.[23] (Balboa Pacific Corporation, 11240 Bloomfield Avenue, Santa Fe Springs, CA 90670; Ph. 562-929-1633 — The Hallwood Group, Inc., 1306 Countryside Place, Smyrna, GA 30080; Ph. 770-436-5027; Fax 770-438-0002)

Duratek[24] has a proprietary system based on superheated steam reforming. The original technology developed by Synthetica, exposed hazardous, infectious, or radioactive waste to superheated steam at high temperatures (about 900°F), causing organic material to vaporize; the vapors were then heated further up to 2,800°F in a chamber where steam reforming processes took place. Duratek has employed the technology to treat pharmaceutical waste, highly contaminated animal carcasses, and radioactive waste. (Duratek, 10100 Old Columbia Road, Columbia, MD 21046; www.gtsduratek.com)

Unitel Technologies[25] is developing two technologies to handle nonhazardous and hazardous wastes including medical waste. These two technologies are intended for large regional treatment centers. In the Skygas system, waste is fed into a reactor, vaporized near an electric arc at 3,500°F, and pyrolyzed to form a gas that can be used as fuel. The other technology, the Cement-Lock system, uses waste fuel to generate high temperatures in a process which gasifies the waste and turns it into powder. The powder residue then would be mixed with cement to make high-performance concrete. (Unitel Technologies, 411 Business Center Drive, Suite 111, Mt. Prospect, IL 60056; Ph. 847-297-2265; Fax 847-297-1365)

Vanguard Research, Inc.[26] (VRI) is developing the Plasma Energy Pyrolysis System (PEPS) using a plasma arc torch. The waste goes through a screw feeder into the process chamber, a refractory-lined steel container where the waste is turned into a vitrified slag. A trough at the bottom of the chamber collects the molten metal and glass which are drained through taps to recover the glassy slag. The product gas passes through a scrubber to neutralize any acid gases and into a thermal oxidizer. There are two possible configurations for PEPS: a fixed unit for large volumes and a mobile unit for on-site treatment. (Vanguard Research, Inc., 8384-C Terminal Road, Lorton, VA 22079; Ph. 703-339-6222; Fax 703-339-6835; www.vriffx.com; info@vripeps.com)

NOTES

1. Based on vendor website, "Medical Waste Reduction System Reverse Polymerization MD-1000" brochure, and CD-ROM obtained in 2001, and personal communication with Lyle Hoegy.
2. Based on CWT brochure obtained in October 1999 and personal communication with Mark Johnson.
3. "Source Sampling for Particulate, Dioxins, Multi-Metals, Hexavalent Chromium, HCl, Opacity, and Gaseous Emissions: Model 100 Bio-Oxidatizer Waste Treatment Unit," (Testing Site: Pinnacle Health at Polyclinic Hospital, Harrisburg, PA), prepared for Bio-Oxidation, Inc. by RAMCON Environmental Corporation, Memphis, TN, March 1998.
4. Based on vendor website, brochures and technical data provided by Bio-Oxidation and Oxidation Technologies from 1993 to 2000, responses to technical questions, site evaluation of the Bio-Oxidizer unit at Chambersburg in Pennsylvania, and personal communications with John Moran and other personnel.
5. I.C. McNeill, L. Memetea, M.H. Mohammed, A.R. Fernandes, and P. Ambidge, "Polychlorinated dibenzodioxins and dibenzofurans in PVC pyrolysis," *Polymer Degradation and Stability*, 62, 145-155 (1998).
6. Y. Yonezawa, S. Saigusa, M. Takhagi, and H. Nishioka, "Mutagenic substances in pyrolysate obtained by burning polyvinylchloride-product at 1000 degrees C," *Mutat. Res*. 422(2), 97-103 (1999).
7. Based on technical data provided by Daystar Technologies and Prometron Technics from 1997 to October 1999, responses to technical questions, and personal communications with H. Matsuda.
8. Based on technical data provided by EPI from 1995 to 1999, personal communications with J. Kenneth Wittle, and various published papers including: A. Wenger, B. Farouk, and J.K. Wittle, "Analysis of Material Recovery in Plasma Arc Melting of Solid Wastes: A Computational Study," J. Air & Waste Manage. Assoc. 49, 279 (March 1999); and J.k. Wittle, R. Hamilton, P. Wilver, and J. Kidd, "The Use of DC Graphite Arc Melter to Process Surrogate Medical Waste Under Pyrolytic Conditions," presented at the 1998 International Conference on Incineration and Thermal Treatment Technologies," Salt Lake City, Utah, May 11-15, 1998.
9. Based on vendor website, brochures and technical data provided by Mason & Hanger from 1990-1992, Plasma Energy Applied Technology from 1993 to 1997, and HI Disposal from 1997 to November 1999, responses to technical questions, and past personal

communications with Don Hawkins, Thomas Damberger, and Ray Dupree.

10. Based on vendor website, brochures and technical data provided by IET from January 1998 to June 1999, and personal communications with Jeffrey Surma.
11. Based on information provided by MSE in 1998 and personal communications with Bob O'Such.
12. Based on technical information provided by PPS from 1998 to 2000, and personal communications with Paul Eckhoff and James Woo.
13. Based on the vendor website and limited information provided by the vendor from 1996 to 1998.
14. Information provided by Elizabeth Crowe, Chemical Weapons Working Group, based on the Assembled Chemical Weapons Assessment Report to Congress, September 30, 1999; see also www.pmacwa.org.
15. Based on brochures and technical data provided by Vance IDS from 1994 to 2000, site inspection of the prototype unit at Tulane University Medical Center, and personal communications with Murry Vance and other personnel.
16. Based on vendor website, brochures and technical data provided by IET from January 1998 to June 1999, and personal communications with Jeffrey Surma.
17. Based on brochures and technical data provided by Vance IDS from 1994 to 2000, and personal communications with Murry Vance and other personnel.
18. Based on vendor brochures and technical data provided by The Carbon Group from 1995 to 1997 and from Vanish Technologies from 1997 to 1999, and personal communications with Bob Olexy, John Self, Bob Kelly, and Joanne Jaeger.
19. Based on brochures and technical data provided by NCE from 1996 to 2000, written responses to technical questions, site evaluation of the TurboClean at the manufacturer's facility in Carrollton, Texas, and personal communications with George Senn and John Butcher, Jr.
20. Based on vendor website.
21. Based on technical data provided by The Hallwood Group in 2001.
22. "Source Test Report: PCB Treatability Demonstration Test on the Pyrolytic Thermal Conversion Unit With a Thermal Oxidizer – Liquid and Solid Feed," Dames & Moore, No. 30990-002-131, prepared for Balboa Pacific Corporation, February 1996.
23. "Source Test Report: Multiple Metals Emissions Testing," Dames & Moore, Job No. 35746-001-131, prepared for Sandia National Laboratories, March 10-14, 1997.
24. Based on vendor website, past material on the Synthetica steam detoxifier, and personal communication with Terry Galloway.
25. Based on personal communication with Unitel Technologies.
26. Based on vendor website.

Chapter 8

Chemical-Based Technologies: Chlorine and Non-Chlorine Based Systems

Hospitals and other health care facilities have used chemical agents routinely for decades, in applications ranging from disinfecting reusable instruments to general cleaning of work surfaces. When applied to medical waste treatment, the main problem is how to ensure contact between the chemical and infectious waste with a high enough concentration and sufficient exposure time to achieve proper levels of disinfection. Chemical-based disinfection technologies generally incorporate internal shredding and mixing to resolve the problem of contact and exposure. To maintain the proper concentration, chemical technologies must be able to replenish chemicals lost through volatilization, decomposition, adsorption on waste surfaces, and interaction with microorganisms. Other factors such as pH, temperature, and the presence of other chemicals that may interfere with the disinfection process should also be considered.

Depending on the nature of the chemicals, occupational exposures of workers to concentrations in the air and through skin contact may be a concern. Since many chemical-based technologies release substantial quantities of liquid effluent or wastewater into the sewer, the releases must comply with limits set in effluent discharge permits. In addition, it is important to determine what the long-term environmental consequences of those releases might be.

In the past, the most common chemical disinfectants for treating medical waste were chlorine-based because of the ability of chlorine and hypochlorite to inactivate a broad range of microorganisms. Solutions of sodium hypochlorite (bleach) were regularly used. Recently, non-chlorine chemical disinfectants have been introduced ino the market, such as peroxyacetic acid (also known as peracetic acid), glutaraldehyde, sodium hydroxide, ozone gas, and calcium oxide. Some of these are commonly used in disinfecting medical instruments.

The technologies in this chapter are divided into chlorine and non-chlorine based technologies, in part because of environmental concerns that have been raised with some chlorinated compounds as discussed below.

Types of Waste Treated

The types of waste commonly treated in chemical-based technologies are: cultures and stocks, sharps, liquid human and animal wastes including blood and body fluids (in some technologies, this may be limited to a certain percentage of the waste), isolation and surgery wastes, laboratory waste (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes in chemical treatment systems.

Volatile and semi-volatile organic compounds, chemotherapeutic wastes, mercury, other hazardous chemical wastes, and radiological wastes should *not* be treated in chemical treatment units. Large metal objects may damage internal shredders.

Emissions and Waste Residues

Since chemical processes usually require shredding, the release of pathogens through aerosol formation may be a concern. Chemical-based technologies commonly operate as closed systems or under negative pressure passing their air exhaust through HEPA and other filters. These safeguards should not be compromised. Another issue relates to occupational exposures to the chemical disinfectant itself through fugitive emissions, accidental leaks or spills from storage containers, discharges from the treatment unit, volatilized chemicals from treated waste or liquid effluent, etc. Chemical disinfectants are sometimes stored in concentrated form, thus increasing the hazards. The study 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 mechanical/chemical treatment facility that exceeded permissible exposure limits set by the Occupational Safety and Health Administration. The highest VOC level in the facility was ethanol, measured at 4732 mg/m^3.

Microbial Inactivation

Microorganisms vary in their resistance to chemical treatment. The least resistant are vegetative bacteria, vegetative fungi, fungal spores, and lipophilic viruses; the more resistant organisms are hydrophilic viruses, mycobacteria, and bacterial spores such as *B. stearothermophilus*.

Tests of microbial inactivation efficacy should be conducted to show that a 10^4 kill or greater of at least *B. stearothermophilus* spores is achieved at the chemical concentrations and treatment conditions of normal operation of the technology.

Advantages and Disadvantages

Chemical treatment technologies have the following advantages:

- The technologies using sodium hypochlorite have been used since the early 1980s and have a long track record. The process is well-understood.
- The technologies are well-automated and easy to use.
- Liquid effluents generally can be discharged into the sanitary sewer.
- No combustion byproducts are produced.
- If the technology incorporates shredding, the waste is rendered unrecognizable.

The disadvantages include the following:

- There are concerns of possible toxic byproducts in the wastewater from large-scale chlorine and hypochlorite systems.
- Chemical hazards are a potential problem with chemical-based systems.
- If hazardous chemicals are in the waste, these toxic contaminants are released into the air and wastewater, remain in the waste to contaminate the landfill, or they may react with the chemical disinfectant forming other compounds which may or may not be hazardous.
- Noise levels, such as from a hammermill process or a shredder, can be very high.
- There may be some offensive odors around some chemical treatment units.
- Any large, hard metal object in the waste can damage mechanical devices such as shredders.

Other Considerations

Below are some ideas to consider when selecting chemical treatment systems:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in a chemical system.
- Work areas should be monitored for ambient concentrations of chemicals to ensure at the very least that OSHA permissible exposure limits are not exceeded.
- Maintain records of chemical or biological indicator tests, treatment parameters (such as chemical concentrations), preventive maintenance activities, and periodic inspections.
- Provide sufficient ventilation to reduce odors and chemical concentrations in air.
- Install emergency wash-down hoses, showers, eyewash stations, and first aid kits specifically designed for accidental chemical exposures. Workers should have chemical-resistant goggles, gloves, aprons, and other personal protective equipment such as respirators appropriate for emergencies given the chemicals in use.
- Provide hearing protection for workers if hammermill operations are too noisy.
- Ask the technology manufacturer what reactions are possible between the disinfectant and chemicals that may inadvertently be present in the waste. Find out how this might affect the process; what hazardous materials, if any, may be produced; what emergency response is needed, and how these problems could be avoided.
- Facilities must report chemical spills (if they exceed specified "reportable quantities") to regulatory agencies as required by law.
- Provide worker training to include: a basic understanding of chemical-based treatment systems, standard operating procedures, occupational safety (Material Safety Data Sheets, toxicity, chemical incompatibilities and reactivities, exposure limits, ergonomics, proper waste handling techniques, personal protective equipment, etc.), recordkeeping, identifying waste that should not be treated in the unit, recognizing technical problems, periodic maintenance schedules, and contingency plans (e.g., what to do in case of a hazardous spill).

CHLORINE-BASED SYSTEMS

Sodium hypochlorite (NaOCl), a commonly used disinfectant in health care facilities, is manufactured by reacting chlorine with sodium hydroxide and water. Household bleach is a 3-6 percent concentration of sodium hypochlorite. It is effective in inactivating bacteria, fungi, and viruses, and in controlling odor. It is used extensively as a disinfectant for drinking water, swimming pools, and sewage treatment. Not surprisingly, it was one of the first chemical disinfectants to be used in treating medical waste.

Under ideal conditions, sodium hypochlorite breaks down to form table salt. In recent years, however, concerns have been raised about small amounts of toxic byproducts

associated with the use of large quantities of chlorine and hypochlorite such as in the pulp and paper industry. Apparently, no studies have been done to establish whether or not this problem exists downstream of chemical treatment facilities for medical waste. It is believed, however, that reactions between chlorine/hypochlorite and organic matter produce trihalomethanes, haloacetic acids, and chlorinated aromatic compounds that are toxic. Furthermore, dioxin has been found in bleached paper products, waste discharges from pulp and paper mills that use chlorine and hypochlorite bleach, and aquatic eco-systems downstream of those mills. Reactions of chlorine with ammonia in the water may also release toxic chloramines.

Chlorine dioxide, ClO_2, has been offered as an alternative to hypochlorite in the pulp and paper, municipal water treatment, and food industries. Chlorine dioxide in air is an unstable gas that decomposes to form toxic chlorine gas and heat. Due to its instability, it is generated and used on site using sodium chlorite, sodium chlorate, or electrochemical means. It is stable as a dilute aqueous solution. Like chlorine and hypochlorite, chlorine dioxide is a strong biocide. Importantly, from an environmental standpoint, chlorine dioxide has the advantage of forming chlorite ion which decomposes to form salt. Because many organic compounds such as ammonia, alcohols, and aromatic compounds do not react readily with chlorine dioxide, there are indications that trihalomethanes, haloacetic acids, dioxin, and other chlorinated byproducts may be significantly reduced. With chlorine dioxide, safety hazards must be considered.

Both chemicals have to be handled carefully. Sodium hypochlorite can irritate the respiratory tract, skin, and eyes. Persons with respiratory and heart disorders may be especially susceptible to the health effects of hypochlorite. The OSHA permissible exposure limit is 0.5 ppm (time-weighted average). Local exhaust ventilation is important. A full-facepiece respirator with acid gas cartridge or a positive-pressure air-supplied respirator (for high concentrations) is needed if ambient concentrations exceed the OSHA limit. Chlorine dioxide is a poisonous gas that is readily soluble in water. It has a maximum recommended limit of 0.1 ppm (8-hour average). A self-contained breathing apparatus is required if ambient concentrations are higher than the limit. Proper ventilation is also vital. Workers should review the Material Safety Data Sheets for the chemicals used to generate chlorine dioxide since the feed chemicals are also hazardous.

The technologies described below use either hypochlorite or chlorine dioxide as the disinfecting agent.

Descriptions of Chlorine-Based Systems

Circle Medical Products[1] (formerly Medical SafeTEC) has been producing a shredder-chemical disinfection system since 1985. Their older models such as *MST 300* have been replaced by a newer model, *LFB 12-5*. The technology uses sodium hypochlorite (bleach) to destroy pathogens. Medical waste is placed on a belt conveyer and transferred under negative pressure into the system where it is soaked in hypochlorite solution. It is then shredded and pulverized in a high-speed three-chambered hammermill. From the hammermill, the material goes to a pressurized tank, where a mixing device saturates the shredded waste at a set pressure. The higher pressure apparently forces sodium hypochlorite deeper into the waste and increases the level of disinfection. The waste is then passed through an extruder to remove excess liquid and reduce the weight of the treated waste, which is augured to an on-site waste container such as a dumpster or compactor. The complete process takes place in about five minutes. At the end of a prescribed number of operating hours, the spent liquids are neutralized, filtered, and discharged to the sewer system. The major components are: feed conveyor, high-speed hammermill, sodium hypochlorite injection system, pressurized kill tank, auger system, HEPA filters, and controls. Processing speeds are rated up to 3,000 pounds per hour. The LFB 12-5 has a capital cost of about $295,000. (Circle Medical Products, Inc., 3950 Culligan Avenue #D, Indianapolis, IN 46218; Ph. 317-541-8080)

MedWaste Technologies Corporation[2] has developed a mobile medical waste treatment unit using sodium hypochlorite as a chemical disinfectant. The waste is shredded and treated with the chemical. The mobile unit can be driven to a hospital where infectious waste is treated on-site and then dumped into the hospital's trash dumpsters to be disposed as regular waste. The company is seeking approval in various states and provides a service to health care facilities. (MedWaste Technologies Corporation, 6830 N. Eldridge Parkway, Building 110, Houston, TX 77041; Ph. 713-849-5480; Fax 713-849-9774; www.medwastetech.com)

Encore[3] combines chemical treatment using chlorine dioxide and an industrial shredder and granulator. A proprietary generation process produces chlorine dioxide on site. The Encore unit is capable of treating 2,500 to 3,000 pounds per hour. The technology is used by Medical Compliance Services, a regional treatment center in Texas. (Medical Compliance Services, Ph. 800-274-4627)

NON-CHLORINE TECHNOLOGIES

The non-chlorine processes are quite varied – from systems that use a gas such as ozone, a liquid such as alkali, or a dry chemical such as calcium oxide. Some chemicals, like ozone, do not physically alter the waste, while others initiate chemical reactions that change the chemical and physical characteristics of the waste. Non-chlorine processes have the advantage of not producing dioxins or other toxic chlorinated byproducts. However, some formulations are proprietary. If so, facilities should request from vendors data on their chemical agents in relation to microbial inactivation, environmental emissions, occupational hazards, etc.

Calcium oxide, also called lime or quicklime, is a white or gray odorless powder produced by heating limestone. It has a myriad of uses including as an ingredient in medicines, water softeners, and cements, as well as in making glass, purifying sugar, and treating soils. It reacts with water to form calcium hydroxide and can irritate the eyes and upper respiratory tract. The NIOSH recommended exposure limit is 2 mg/m^3.

Ozone is an oxidizing agent that contains three atoms of oxygen (O_3) rather than the usual two (O_2). Trace amounts of ozone are formed by the sun or when lightning strikes. It is an component of smog and also makes up a protective layer around the earth. Because it is highly reactive, it breaks down easily back to its more stable form (O_2). Ozone is used in drinking water treatment, industrial and municipal wastewater treatment, odor control, air purification, agriculture, and food processing. Ozone can cause eye, nose, and respiratory tract irritation. Workplace air should not contain more than 0.1 ppm of ozone.

Alkali or caustic, such as sodium or potassium hydroxide, are extremely corrosive. They are used in chemical manufacturing, pH control, soap production, cleaners, textile processing, and a wider range of other uses. Solid cakes or pellets of the alkali react strongly with water releasing heat. Contact with various chemicals including metals may cause fire. Concentrated alkaline solutions are corrosive enough to cause permanent scarring, blindness, or even death. Aerosols of the alkali can cause lung injury. Exposure limits are 2 mg/m^3.

Peracetic acid (peroxyacetic acid) is used in hospitals to sterilize the surfaces of medical instruments and may be found in a hospital's laboratory, central supply, and patient care units. It is a strong skin, eye, and mucous membrane irritant and continued skin exposure may cause liver, kidney, and heart problems. Direct skin contact and exposure to vapors should be restricted. Peracetic acid breaks down eventually into an acetic acid solution (vinegar).

The types of waste treated in non-chlorine technologies depend on the specific technology and disinfecting agent used. For example, alkaline hydrolysis is especially suited for tissue waste, animal carcasses, anatomical parts, blood, and body fluids; it can also destroy aldehydes, fixatives, and cytotoxic agents. Peracetic acid-based technologies equipped with mechanical destruction can handle sharps, glassware, laboratory waste, blood, other body fluids, cultures, and other contaminated materials.

Descriptions of Non-Chlorine Based Systems

The **Steris EcoCycle 10**[4] is a compact system designed to treat small volumes and can be used at or near the point of generation of waste. It treats five to eight pounds of waste every 10 minutes including syringes, needles, glassware, laboratory waste, blood, other body fluids, specimens, cultures, and other contaminated materials. The waste is collected in a portable processing chamber at the point of generation. When filled, the chamber is transported to a processor using an optional caddy. A peracetic acid-based decontaminant in a single-use container is dropped into the chamber (the specific formulation used depends on how much fluid is in the waste). As the processing cycle begins, the material is ground up, breaking open the decontaminant vial and chemically disinfecting the waste in 10-12 minutes. The processing cap contains a replaceable HEPA filter to prevent the escape of aerosolized pathogens. At the end of the cycle, the chamber is put on a tilt bracket and its contents are dumped into the liquid separation unit which has a plastic bag. Water is used to rinse the waste. The liquid effluent is filtered before being discharged into the sewer drain, while the waste is retained in the plastic bag for disposal as regular trash. The chemical byproducts of the decontaminant are acetic acid and some hydrogen peroxide which eventually break down into a weak vinegar solution. Microbial inactivation tests[5] demonstrate a 6 to 8 $\log_{10}$ kill for 13 microorganisms including *B. subtilis*, *Staphylococcus aureus, Pseudomonas aeruginosa*, bacteriophage MS-2, *Mycobacterium bovis*, Poliovirus, *Aspergillus fumigatus, Candida albicans*, and *Giardia muris*. Steris markets its decontaminant in two doses: STERIS-SW mainly for solid wastes with low organic load; STERIS-LW for waste with high amounts of liquids and a high organic load. EcoCycle 10 units have dimensions of 45.5" W x 31" D x 52" H and require an electrical connection (208 V, 1-phase, 30 A), water (40-100 psi, 1.5 gallons per cycle) and a drain. The units are manufactured by Steris on demand only and sell for about $20,000. (Steris Corporation, 5960 Heisley Road, Mentor, OH 44060; Ph. 800-548-4873 or 440-354-2600; Fax 440-639-4450; www.steris.com)

Waste Reduction By Waste Reduction, Inc.[6] or **WR²** offers an alkaline digestion process to convert animal and microbial tissues into a neutral, decontaminated, aqueous solution. The WR² process utilizes alkaline hydrolysis at elevated temperatures. The alkali also destroys fixatives in tissues and various hazardous chemicals including formaldehyde and glutaraldehyde.[7] The Tissue Digester is an insulated, steam-jacketed, stainless steel tank with a retainer basket for bone remnants and a clam-shell lid. After the waste is loaded in the hermetically sealed tank, alkali in amounts proportional to the quantity of tissue in the tank is added along with water. The contents are heated usually to between 230° to 260°F (110° to 127°C) or up to about 300°F (150°C) while being stirred. The tanks are rated at 100 psia but are operated at less than 70 psia. Depending on the amount of alkali and temperature used, digestion times range from six to eight hours. The technology does not handle the full range of waste streams in a health care facility but is only designed for tissue wastes including anatomical parts, organs, placentas, blood, body fluids, specimens, degradable bags, degradable fabrics (such as Isolyser's Orex and Enviroguard), and animal carcasses.

The WR² technology is a non-incineration alternative that can handle chemotherapy waste. All antineoplastic drugs listed by the U.S. EPA as hazardous waste are destroyed by the hot alkali solution. Other antineoplastic agents, especially alkylating agents based on nitrogen mustard, can be decomposed by alkaline hydrolysis but facilities should check with the vendor and regulators to ensure that all specific chemotherapy agents in their waste can indeed be destroyed using this technology.

Other types of waste should not be treated unless it can be shown that the heated alkali can breakdown the material without any adverse environmental impact. (Animal carcasses labeled with radionuclides have been treated using the WR² process; in the case of ^{125}I and ^{131}I, for example, the radioiodine after treatment in the WR² process was not found in the dry bones but was distributed in the digest and wash.[8] In general, low-level radioactive aqueous waste containing low-activity radionuclides with short half-lives can be "stored for decay" [i.e., kept secure in a storage area usually for 10 times the half-life], subsequently surveyed to confirm decay to background levels, and only then disposed in the sewer [assuming there are no other hazardous properties]. Other federal or local license and regulatory conditions may apply. Radioactive waste with high-activity radionuclides and long half-lives should not be released down the sewer but should be transferred to an authorized radioactive waste disposal site.)

The byproducts from the WR² process are biodegradable: mineral constituents of bones and teeth (which can be crushed and recovered as sterile bone meal) and an aqueous solution of peptide chains, amino acids, sugars, soaps, and salts. Facilities should check with local municipal districts to ensure that the alkaline liquid waste can be discharged to the sewer. An excess of hydroxide could lead to a pH greater than 12.5 for the liquid waste which would be classified as hazardous waste. Materials such as ceramics, stainless steel catheters and needles, rubber, etc., are unaffected by alkaline hydrolysis and are retained in the processing basket from which they can be recovered after the treatment. Microbial inactivation efficacy tests[9] showed a greater than 99.9 percent kill rate for the following microorganisms: *Aspergillus fumigatus*, *B. subtilis*, *Pseudomonas aeruginosa*, *Giardia* cysts, *Mycobacterium bovis* BCG, *Giardia muris*, MS-2 bacteriophage, *Staphylococcus aureaus*, *Mycobacterium fortuitum*, and *Candida albicans*. Because the process hydrolyzes proteins, it is believed that prions cannot survive the process intact.[10] In light of the growing concern over spongiform encephalopathies (e.g. mad cow disease), this would be important to verify when dealing with animal carcasses.

The process is automated and designed to be left unattended during the processing cycle. Digesters range in size from five to 150 gallons (19 to 568 liters) or more, and may include a weighing system, chart recorder for documentation, and electrical heating. Among the more common hospital sizes are models *100-18-20* and *100-30-26* which handle 80 and 200 pounds, respectively. WR² recently opened a European subsidiary and acquired Sterile Technologies Industries described above under steam treatment systems. (Waste Reduction by Waste Reduction, Inc., 5711 W. Minnesota Street, Indianapolis, IN 46241; Ph. 317-484-4200; Fax 317-484-4201; www.wr2.net; wr2@wr2.net)

Lynntech[11] has been developing a technology that uses ozone as the decontaminant. Ozone is a strong oxidant that can destroy microorganisms and converts readily to molecular oxygen. In the Lynntech system, medical waste is placed in a treatment chamber containing a slow-speed, high-torque shredder. An electrochemical ozone generator produces five pounds of ozone per day at concentrations as much as 18 wt% ozone under pressure using water as a source. Water is circulated between a storage reservoir and an electrochemical cell stack in which ozone and oxygen are generated at room temperature. When 100 kg of shredded medical waste are exposed to about 14 wt% ozone for four hours, a 4 log reduction of *B. subtilis* endospores is achieved. A pilot-scale unit was tested for three weeks at Lackland Air Force Base in Texas. The technology can be used as a field-portable disinfection system. Ozonation technology is also being

considered for disinfection of medical instruments, treatment of contaminated groundwater, and other applications. A demonstration unit is capable of treating to 220- to 518-pound batches (100 to 235 kg). (Lynntech, Inc., 7610 Eastmark Drive, Suite 105, College Station, TX 77840; Ph. 409-693-0017; Fax 409-764-7479)

MCM Environmental Technologies[12] has developed SteriMed, a compact automated system (the size of a washer/dryer) which combines shredding, mixing, and disinfection using a proprietary disinfectant. According to the vendor, the proprietary disinfectant called SteriCid deodorizes waste and is 90 percent biodegradable. As with all proprietary formulations, facilities should ask the vendor for data on emissions and potential occupational hazards. Tests[13] done for MCM Environmental Technologies show that at 0.5% SteriCid for 12-minute exposures, greater than 6 Log10 kill can be achieved with *B. subtilis, S. aureus, C. albicans, Aspergillus niger, M. phlei, M. bovis var* BCG, *P. aeruginosa*, *E. aerones, Giardia* cysts, and Polio virus Type 2 at various exposure times. SteriMed treats up to 20 gallons per 15-minute cycle. SteriMed has reportedly received approval as an alternative technology in New York and in 23 other states. There is a beta site at Gambro Healthcare facilities in St. Louis, MO.[14] (MCM Environmental Technologies, Moledet, M.P. Gilboa 19130 Israel; Ph. 972-6-653-1104)

The **Matrix**[15] is a large-scale treatment system that decontaminates and deodorizes the waste using disinfecting agents. The disinfecting agents are themselves converted to water, clays, and carbonates. The waste is shredded and turns into an inert, amorphous, solid product. Operating costs are reported to be low. (Matrix Technology Pty. Ltd., P.O. Box 1213, Cairns, Queensland, Australia 4870; Ph. 617-40512955; Fax 617-40518709; www.iig.com.au/matrix)

The **MMT 3000**[16] is a dry chemical treatment technology incorporating physical destruction in a unique horizontal shredder along with chemical disinfection using a dry inorganic (calcium oxide-based) powder called Cold-Ster. Microbial inactivation tests[17] showed a greater than 6 $\log_{10}$ kill for *B. subtilis* and *B. stearothermophilus*. Waste is shredded and the chemical is added with a small amount of water. The process takes about six minutes and does not produce a liquid effluent. The unit was previously marketed by Medical Materials & Technology but is now offered by Positive Impact Waste Solutions, Inc. (4110 Rice Dryer Boulevard, Pearland, TX 77581; Ph. 281-412-9991; Fax 281-997-1007).

Premier Medical Technology[18] (PMT) has developed a system that combines physical destruction with a proprietary dry chemical powder. Studies[19] commissioned by PMT have shown that the powder inactivates *B. subtilis* and *B. stearothermophilus* (greater than 6 $\log_{10}$ kill), HIV (5 $\log_{10}$ kill), duck hepatitis B virus, *Mycobacterium chelonei*, *Staphylococcus aureus*, *Pseudomonas cepacea*, and Vesicular stomatitis virus. The medical waste is loaded into a hopper and sent through a high-torque cutting and grinding process while being mixed with a dry, inorganic disinfectant. The mixture then goes through a high-speed shredder and sent to a trash compactor. The major components include a waste measuring and loading system, two cutting assemblies, two mixing augers, weighing/feed subsystem, water subsystem, waste pretreatment, air filtration, and controls. The unit, with capacities of 600 to 900 pounds per hour (272 to 408 kg/hr), requires a water supply and a 460V, 3-phase, 150A supply. (Premier Medical Technology, Inc., 525 North Sam Houston Parkway East, Houston, TX 77060; Ph. 281-448-2399)

Delphi Research[20] is developing a electrocatalytic wet oxidation process called MEDETOX to treat medical waste, as well as hazardous and radioactive wastes. The system uses a patented combination of homogeneous metal catalysts and co-catalysts in a dilute acidic solution. As waste is introduced in the reactor, organic material are oxidized in the solution; many metals are dissolved, concentrated, and may be recovered. (Delphi Research, Inc., 701 Haines Avenue NW, Albuquerque, NM 87102; Ph. 505-292-9315)

CerOx Corporation[21] is developing a catalyzed electrochemical oxidation technology that uses cerium, a metal catalyst, in an acidic solution to oxidize organic waste in a reactor. It is being developed to destroy cytotoxic waste, pharmaceuticals, alcohols, chlorinated solvents, dioxins, PCBs, pesticides, low-level radioactive waste, and other organics. (CerOx Corporation, 760 San Aleso Avenue, Sunnyvale, CA 94086; Ph. 408-744-9180; www.cerox.com)

WR2[22]

Description
(See above)

Models-Capacities
Small: Model *#100-18-20* – 50 lbs or 23 kg
Medium: Model *#100-30-26* – 200 lbs or 91 kg; *#100-48-32* – 750 lbs or 340 kg
Large: Model *#100-48-52* – 1,500 lbs or 682 kg; *#100-72-52* – 3,000 lbs or 1364 kg; *#100-96-68* – 7,000 lbs or 3,200 kg

Approximate Dimensions (Vessel diameter and height, not including lid lifts)
Model *#100-18-20* – 18" dia x 20" H; *#100-30-26* – 30" x 26"; *#100-48-32* – 48" x 32"; *#100-48-52* – 58" x 52"; *#100-72-52* – 72" x 52"; *#100-96-68* – 96" x 68"

Approximate Energy Consumption
Model *#100-18-20* – 0.104 kWh per lb of waste; *#100-30-26* – 0.041; *#100-48-32* – 0.011; *#100-48-52* – 0.005; *#100-72-52* – 0.005"; *#100-96-68* – 0.002

Typical Installation Requirements
Steam supply, electrical service, hot and cold water, diked area and floor drain, eye wash and chemical shower stations, sink, cabinet for personnel protection equipment, and area for chemical storage tanks

Features & Options
WR^2 supplies processing baskets, basket hoists, automated hydraulic lid latching system, fully automated cycle controls, handling carts, gurneys, soluble processing bags, and alkali. Remote computer monitoring is also available.

Stage of Commercialization
Fully commercialized

Approximate Costs
N/a

Vendor Information
Waste Reduction by Waste Reduction, Inc., 5711 W. Minnesota Street, Indianapolis, IN 46241; Ph. 317-484-4200; Fax 317-484-4201; www.wr2.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.*

OTHER SYSTEMS

Not included in this report are technologies that use chemical compounds not necessarily for their disinfecting potential but for their ability to solidify or encapsulate waste. Examples are: Premicide, Premisorb, Canister Express, and Solidifier from OBF Industries (Downers Grove, IL) for liquid medical waste and suction canisters; and LTS Plus, ALDEX, and Raysorb made by Isolyser (Norcross, GA) for liquids, aldehydes, and x-ray wastes, respectively. Some encapsulating agents are fast-acting acrylic or epoxy-based polymers incorporating anti-microbial agents to disinfect the waste. Many claim to be non-toxic and to reduce biohazardous fluids into non-hazardous materials.

Any chemical disinfectant that makes anti-microbial claims must be registered with the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Recently, the State of California withdrew the approval of one liquid treatment system due to questions about its ability to achieve a 4 $\log_{10}$ kill of *Bacillus* spores in 100 percent serum solution. In another case, the EPA penalized a company that makes solidifiers and fluid absorbents due to unsubstantiated claims of germ-killing effectiveness.[23]

Facilities should ask for and carefully review results of microbial inactivation efficacy tests, TCLP, toxicity tests, occupational exposure tests, etc. to ascertain claims that the resulting solidified waste is indeed disinfected and non-hazardous. Because organic material in liquid medical waste can lessen anti-microbial effectiveness, tests for disinfection should be conducted using 100% serum at the use dilution specified on the product label. Facilities should also determine from the vendors whether the solidifying and sanitizing agents are themselves hazardous substances and whether the resulting encapsulated waste can be disposed in a landfill. Some states may not recognize encapsulation as an accepted treatment method for medical waste.

NOTES

1. Based on vendor literature and technical data provided by Medical SafeTEC, later Circle Medical Products, from 1994 to 2000, responses to technical questions, and personal communications with Jon Watson.
2. Based on vendor brochure provided by MTC in 2000.
3. Based on limited information provided in 1995 and past personal communication with Ottley Smith and Nelson Slavik.
4. Based on vendor website, literature provided by Ecomed beginning in 1993 and by Steris from 1995 to 1999, and personal communications with various Steris personnel.
5. W.L. Turnberg. *Biohazardous Waste: Risk Assessment, Policy and Management.* (New York, NY: John Wiley & Sons, Inc. 1996).
6. Based on vendor website, brochures and technical data provided by WR2 from 1998 to 2000, and personal communications with Gordon Kaye and John Wilson.
7. Data provided by Dr. Gordon Kaye, WR2.

8. Data on the destruction of radioactive tissue provided by WR2.
9. G.I. Kaye, P.B. Weber, A. Evans, and R.A. Venezia, "Efficacy of Alkaline Hydrolysis as an Alternative Method for Treatment and Disposal of Infectious Animal Waste," *Contemporary Topics* (American Association for Laboratory Animal Science), 37(3), 43-46, May 1998; Dr. Edward Jarroll (Cleveland State University), "Evaluation of WR2 Model 100 Animal Tissue Digestor for Inactivation of *Giardia* Cysts: Final Report," July 23, 1996 (copy of report provided by WR2).
10. "Description of the WR2 Process," Waste Reduction by Waste Reduction, Inc., Troy, NY, August 1997.
11. Based on technical data provided by Lynntech from 1998 to 2000, and personal communications with Tom Rogers.
12. Based on vendor website and literature obtained in 2000.
13. R. Colodner and A. Shneor, "'Sterimed' – Medical Waste Treatment System Efficacy Tests – Final Report," Haemek Medical Center Microbiology Laboratory (Israel), 1998; S. Trask and R. Tilton, "Stericid for Sterimed Efficacy Testing," BBI Clinical Laboratories, New Britain, CT, November 21, 1997; and E. Jarroll (Northwestern University), "Evaluation of a Medical Waste Treatment System for Inactivation of *Giardia* Cysts," consultant's report, 1997.
14. S. Bander and M. Rothstein, "Sterimed beta Site-Testing Final Report," GAMBRO Healthcare, St. Louis, MO, (no date).
15. Based on vendor website.
16. Based on vendor literature provided by MMT in 1996 and personal communication with Positive Impact Waste Solutions in 1999.
17. W.L. Turnberg. *Biohazardous Waste: Risk Assessment, Policy and Management.* (New York, NY: John Wiley & Sons, Inc. 1996).
18. Based on vendor literature provided by PMT from 1993 to 1995, and past personal communications with Terry Shelton and Dick Taylor.
19. Studies by Prof. Miles Cloyd, Department of Microbiology, University of Texas Medical Branch at Galveston, August 13, 1992; Dr. John Pugh, Fox Chase Cancer Center, Philadelphia, PA, May 20, 1993; Dr. Howard Gratzner, Consultants in Biotechnology, Houston, TX, October 9, 1991, May 11, 1992, and March 23, 1993.
20. Based on technical data provided by Delphi Research in 1995.
21. Based on vendor website.
22. Based on vendor website, brochures and technical data provided by WR2 from 1998 to 2000, and personal communications with Gordon Kaye and John Wilson.
23. "In Precedent-Setting Case, Maker of 'Antibacterial' Hospital Products Settle with EPA," press release, EPA Region 2, New York, November 9, 1998.

Chapter 9

Irradiation, Biological, and Other Technologies: E-Beam, Biological, and Sharps Treatment Systems

This chapter discusses other technologies that use irradiative and biological processes. The presentation on irradiation technology focuses on electron beam systems. There have been very few biological systems designed for medical waste treatment. Biological treatment technologies are still in the research and development phase. Because occupational injuries from needles and syringes are a problem in health care facilities, a discussion of sharps waste treatment technologies is presented at the end of this chapter. These sharps technologies are small portable units that operate on the principles of thermal or chemical treatment.

IRRADIATION TECHNOLOGIES

Overview of the Technology

When electromagnetic radiation has high enough energy to knock out electrons from their atomic orbits, it is referred to as **ionizing radiation**; examples are x-rays and gamma rays. (**Non-ionizing radiation**, such as microwaves and visible light, do not have sufficient energy to remove electrons.) If ionizing radiation interacts with a cell, its main target is the DNA in the nucleus. At sufficiently high doses of ionizing radiation, extensive damage is done to DNA leading to cell death. The ionizing radiation also creates so-called free radicals that cause further damage by reacting with macromolecules in the cell (e.g., proteins, enzymes, etc.). Ionizing radiation can be obtained using radioactive materials, such as **Cobalt-60**, that emit high-speed gamma rays. **UV-C** or ultraviolet radiation in the C range (253.7 nm), also known as germicidal or shortwave UV, is another kind of ionizing radiation and can destroy cells under the proper conditions. UV-C can be generated using special lamps and had been employed as a supplement to alternative treatment technologies to inactivate aerosolized pathogens from shredders and other mechanical devices.

Another technique for producing ionizing radiation is to use an "electron gun" from which a beam of high-energy electrons is propelled at high speed to strike against a target. When energy is applied to a material (called a *cathode*) with loosely bound electrons, a stream of electrons is released. The **electron beam** can be focused using electric and magnetic fields to cause it to bombard a target (called the *anode*). The energy of the electrons measured in *electron-volts* (eV) is determined by the voltage difference between the cathode and anode, and by the current. If infectious waste is in the path of the beam, the electron shower destroys microorganisms by chemical dissociation, the rupture of cell walls, and destruction of DNA and other macromolecules. As e-beams strike metals in the waste, x-rays may also be produced. These x-rays also interact with molecules causing chemical bonds to break. The e-beam converts some oxygen in air into ozone, which itself has disinfecting and deodorizing properties. The high-energy electrons, together with x-rays, free radicals, and ozone, destroy viruses, fungi, bacteria, parasites, spores, and other microorganisms, as well as odors in the waste. The radiation energy absorbed by the waste is referred to as the *absorbed dose* or simply, dose, and is measured in *grays* (Gy); in the past, the unit of *rads* was commonly used (1 Gy = 100 rads). To determine the proper dose, technology manufacturers generally measure doses in various parts of the treatment area and correlate those to the levels of microbial inactivation required.

A product of the nuclear and defense industries, electron beam (or e-beam) technology has been around for a few decades. It is also used in other applications, such as polymer processing, tire manufacturing, and sterilization of medical products. Unlike cobalt-60, e-beam technology does not use radioactive sources and has no residual radiation once the e-beam system is turned off. One area of debate, however, is the issue of induced radioactivity. E-beam manufacturers argue that radioactivity cannot be induced unless very high energies are used, e.g., above 10 or 16 MeV (mega-electronvolts). Others have stated that low levels of radioactivity may be induced at much lower energies. This argument has arisen in the context of the public controversy over food irradiation using e-beam technology.

How It Works

Electron beam technologies are highly automated and computer controlled. In general, e-beam systems consist of: a power supply; a beam accelerator where the electrons are generated, accelerated, and directed towards the target; a scanning system which delivers the required dose; a cooling system to cool the accelerator and other assemblies; a vacuum system to maintain a vacuum in the

accelerator; a shield to protect workers; a conveyor system to transport the waste; and sensors and controls. The shielding system could be in the form of a concrete vault, an underground cavity, or an integral shield around the treatment area. E-beams do not alter the physical characteristics of the waste except perhaps to raise the temperature a few degrees. As such, e-beam technologies require shredders or other mechanical device in the post-processing stage to render the waste unrecognizable and reduce waste volume.

Types of Waste Treated

The types of waste commonly treated in an e-beam technology equipped with a mechanical destruction process are: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory waste (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. Ethical, legal, cultural, and other considerations may preclude treatment of human anatomical wastes.

Volatile and semi-volatile organic compounds, chemotherapeutic wastes, mercury, other hazardous chemical wastes, and radiological wastes should *not* be treated in e-beam units.

Emissions and Waste Residues

E-beam systems do not create any pollutant emissions except possibly for small amounts of ozone which breaks down to diatomic oxygen (O_2). The residual ozone helps remove odors and contributes to the disinfection process in the treatment chamber, but it should be converted back to diatomic oxygen before being released into the environment or workspace. The waste residue looks exactly as it did before treatment, since e-beam irradiation does not change the physical characteristics of the waste. Therefore, a mechanical process is needed to render the treated waste unrecognizable and reduce volume. E-beam systems may contain lead in the shielding; the lead should be recycled or treated as hazardous waste after the e-beam unit is decommissioned.

Microbial Inactivation

Bacteria exhibit varying degrees of resistance to radiation, depending, in large part, on their ability to repair damage to their DNA from irradiation. Depending on the dose, bacterial cells may not be killed outright but their ability to reproduce is impaired. *B. stearothermophilus* and *B. subtilis* spores have been recommended for demonstrating microbial inactivation by irradiation. However, *B. pumilus* spores are more resistant to irradiation and have been used as a standard biological indicator in the sterilization of medical products by irradiation. Other biological indicators even more resistant to radiation, such as *Deinococcus radiodurans*, can provide a very stringent measure and add a margin of safety, if needed.

Advantages and Disadvantages

E-beam treatment technologies have the following advantages:

- The basic technology has been used in other applications for about two decades and is familiar to hospital staff involved in cancer therapy.
- E-beam technology does not produce any toxic emissions (except for small amounts of ozone) and there are no liquid effluents.
- Unlike cobalt-60, there is no ionizing radiation after the machine is turned off.
- It is a room-temperature process and nothing is added to the waste – no steam, water, chemicals, heated air, etc.
- The technology is well-automated and requires little operator time.
- The e-beam technology itself (i.e., excluding shredders or compactors) is noiseless.
- It has a low operating cost.

The disadvantages include the following:

- Personnel must be protected from radiation exposure.
- If an integral shield is not part of the design, the e-beam system requires a concrete shield several feet thick or an underground structure, either of which adds significantly to the installed capital cost.
- Ozone off-gas needs to be removed before the exhaust is released to the atmosphere.
- In relation to food irradiation, some groups have raised the possibility that low-levels of radioactivity may be induced. This is an area that needs more investigation.
- The basic technology does not reduce waste volume or make the waste unrecognizable unless a shredder or other mechanical device is added as a post-treatment step.
- Any large, hard metal object in the waste can damage any shredder or grinder.

Other Considerations

Below are some suggestions to consider when selecting e-beam systems:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in the e-beam system.
- Work areas should be monitored for ozone concentrations to ensure that OSHA permissible exposure limits are not exceeded.

- Workers should be monitored for possible exposure to incidental radiation. The maximum permissible dose for an adult is set by the U.S. Nuclear Regulatory Commission at 5 rem per year. (A rem is another measure of dose, similar to a rad, but it factors in biological damage; the newer unit, the sievert (Sv), is equal to 100 rem.)
- Ensure that safety locks are in place and fully functional to prevent accidental exposure in case a person unexpectedly enters the shielded vault or opens a loading port.
- Maintain records of biological indicator tests, treatment parameters (radiation doses), preventive maintenance activities, and periodic inspections.
- Review the scientific literature on the issue of induced radiation to determine the electron energy level below which induced radiation is not a problem.
- Provide worker training to include: a basic understanding of e-beam technology, standard operating procedures, occupational safety (biological effects of ionizing radiation, maximum permissible dose, "as low as reasonably achievable" or ALARA programs, ergonomics, proper waste handling techniques, personal protective equipment, etc.), record keeping, identifying waste that should not be treated in the unit, recognizing technical problems, periodic maintenance schedules, and contingency plans (e.g., what to do in case of a spill or power outage).

Descriptions of Electron Beam-Based Systems

BioSterile Technology[1] has developed a compact electron beam system intended as an on-site unit to treat medical waste. The system uses a 5 MeV, 2 kW unit capable of handling about 400 to 550 pounds per hour (180 to 225 Kg/hr). Waste is placed in a treatment chamber that has a rotating turntable with dual loading ports on opposite sides. The turntable rotates by means of a motor. Electrons are accelerated using radiofrequency towards the irradiation chamber. A beam that scans a magnetic coil directs the beam along the breadth of the chamber to ensure a uniform dose. A typical cycle is about 2 minutes. A proprietary dose-measurement system verifies and records the treatment parameters to document disinfection. An integral radiation shield encloses the accelerator and treatment chamber. There are also mechanical interlocks and other safety features. The system is automated such that only one operator is needed. The operator can select modes of operation, depending on the type of waste. The Biosiris uses an 85 sq. ft. floor space (9 sq m) and standard 208 V, 3-phase electrical power. It uses very little electricity, around 0.035 kWh per hour. Volume reduction through mechanical destruction (shredder, grinder, compactor, etc.) is optional. Approximate capital cost for a unit is $350,000. BioSterile Technology is seeking a hospital site to demonstrate their e-beam system. (BioSterile Technology, Inc., 4104 Merchant Road, Fort Wayne, IN 46818; Ph. 888-710-3792 or 219-489-2961; Fax 219-489-3654; www.biosterile.com; info@biosterile.com)

The University of Miami's Laboratories for Pollution Control Technologies,[2] in association with the UM/Jackson Memorial Medical Center, has developed a high-energy electron beam medical waste treatment facility. With this technology, the waste is placed in basket-like containers or plastic-lined boxes and is brought to the beam by means of a conveyor system. By controlling the speed of the conveyor, the computer applies the proper dose. The conveyor system is designed such that the waste passes the beam twice, with the other side of the container facing the beam the second time around. The treated waste is transported out of the vault by the conveyor and brought to a shredder where the decontaminated waste can be chopped up for disposal in a sanitary landfill. The e-beam facility is capable of treating 400 pounds per hour (180 kg/hr) of medical waste and uses 2,082 sq ft of space including shielded vault, control room, and waste holding area. The electron beam system consists primarily of a processor-controlled high-voltage source, a water-cooled electron beam accelerator, scan horn assembly, beam stopper, conveyor system, shredder, and computer controls. An ozone-removal system is used as air is vented to the outside. Remote cameras and other instrumentation monitor the system. The irradiation vault is enclosed in a thick concrete shield to prevent occupational exposure to incidental radiation. Once the system is shut down, the electron beam and x-ray production cease. Typical electrical requirements are 380/220 VAC, 40 A, 3-phase. Energy consumption is estimated at 0.04 kWh per pound of waste treated. The University's e-beam facility is licensed as a treatment facility in Florida. Until recently, the facility had been using an 8 MeV electron accelerator. The university is seeking funds to continue research and development on a smaller 4 MeV system. (Prof. Charles Kurucz or Dean Thomas Waite, Laboratories for Pollution Control Technologies, University of Miami, P.O. Box 248294, Coral Gables, FL 33124; Ph. 305-284-2423 or 284-2908; Fax 305-284-2321 or 305-284-2885)

Iotron Technologies uses electron beam irradiation to sterilize food products, medical devices, and other materials. Although not currently used for medical waste, a similar Iotron design has been considered for application

to medical waste treatment. (Iotron Technologies, Inc., 1425 Kebet Way, Port Coquitlam, V2C 6L3, BC, Canada; Ph. 604-945-8838; Fax 604-945-8827)

BIOLOGICAL SYSTEMS

Bio Conversion Technologies Inc.[3] (BCTI), a division of Biomedical Disposal, Inc., is developing a medical waste treatment system using biological processes. A prototype of the "Bio-Converter" was tested in Virginia. It uses an enzyme mixture to decontaminate medical waste and the resulting sludge is put through an extruder used to remove water for sewage disposal. The technology is suited for large applications (10 tons/day) and is also being developed for use in the agricultural sector to break down animal waste. The emerging biological treatment technology was developed after six years of research and development work involving resources from Virginia Tech, The University of Virginia, and The Medical College of Virginia. The system has a delivery hopper, grinder with HEPA filter, reaction chamber tank where waste is exposed to a solution of enzymes, and a separator where the slurry is separated into liquid and solid waste streams. The liquid is sent to the sewer and solid waste is send to a landfill (the solids from animal waste may be recycled as compost). The technology requires regulation of temperature, pH, enzyme level, and other variables. The unit is being designed for a regional medical waste treatment center. BCTI is currently working to bring in organizations with engineering and financial resources to complete the development of the technology. Its parent company, Biomedical Disposal, makes needle destruction technologies. (Bio Conversion Technologies, Inc. (BCTI) c/o Biomedical Disposal, Inc., 3690 Holcomb Bridge Road, Norcross, GA 30092; Ph. 770-300-9595; Fax 770-300-9599)

SMALL SHARPS-TREATMENT UNITS

Occupational injuries from needles and syringes are a problem facing all health care providers. It has been estimated that 600,000 to 800,000 nurses, physicians and other health care workers suffer needlestick and other percutaneous injuries due to sharps. Not all injuries result in infections but the transmission of bloodborne diseases from contaminated sharps is always possible. Three diseases in particular—Hepatitis C virus (HCV), Hepatitis B virus (HBV) and human immunodeficiency virus (HIV)—are of great concern. Most of these injuries can be prevented by the use of safer devices such as needleless systems, devices with retractable or blunt needles, or other so-called safe needle devices with built-in safety features. The passage of the Needlestick Safety and Prevention Act makes clear the responsibility of employers to reduce the risk of injuries to workers by requiring the use of sharps with engineered sharps injury protection and encourages manufacturers of medical sharps to increase the number of safer devices in the market. Another way of helping to reduce the risk of needlesticks is by using sharps waste treatment technologies near the point of use. However, the "engineering controls" prioritized in the Needlestick Safety and Prevention Act refer to engineered sharps injury protection and needleless systems; they do not include sharps waste treatment.

Facilities must weigh the advantages and disadvantages of different sharps management approaches: a small sharps-treatment system at or near the point of use (such as the technologies shown below), sharps collection followed by treatment in an on-site non-incineration technology (many of the treatment alternatives presented in this report can handle sharps waste), or sharps collection and transport to an off-site treatment facility. Several of the small technologies below destroy needle portions only. They employ a disposable container that can hold the remains of several thousand needles. Other technologies allow the user to encapsulate the entire syringe using plastic plugs which adds to plastic waste in landfills. On the other hand, some contractors provide reusable containers that minimize overall waste. Facilities should consider which approach best enhances occupational safety and health for their workers and which is the most cost-effective approach, while minimizing the problem of overfilled containers, reducing the risks associated with transport, and cutting down on overall waste.

Should the facility decide on installing small sharps treatment systems on site, several issues should be addressed. Since some of the sharps treatment technologies employ high-heat thermal processes, facilities should check to make sure that they could be used in environments where flammable gases or liquids may be present. Facilities should request data on microbial inactivation efficacy, environmental emissions, how the treated sharps should be disposed, occupational safety, material safety data sheets (which should include the composition of any disinfecting solution used) or FIFRA registration where applicable, and other relevant information. If the technology encapsulates sharps into a plastic disk or plug, facilities should check if sharp edges or points can protrude from the solid plug. Some states may not recognize encapsulation as a treatment method for sharps.

NOTE: The following information, taken directly from vendor literature, is not intended to be a comprehensive list. The technologies are presented as examples of sharps

waste treatment systems. These sharps treatment technologies do not constitute a "sharp with engineered injury protections" as defined in the 2000 Federal Needlestick Safety and Prevention Act (PL 106-430).

Medical Disposal Devices offers a small device to vaporize needles using a high-temperature oxidation process. The device can be mounted on a wall or operated on a countertop. A sensor automatically activates the device. A disposable cartridge can hold the residues of 2,500 to 3,500 needles. Its dimensions are 10" x 4-1/2" x 3-1/2" and it weighs about 7-1/2 pounds. The cost of the unit is around $600. (Medical Disposal Devices, P.O. Box 523, 11 Halls Road, Old Lyme, CT 06371; Ph. 888-881-3477; Fax 860-434-3690; www.meddisposal.com; mdd@meddisposal.com)

Medical Innovations offers the TAPS Processor, a small countertop device to treat up to 1.6 quarts (1.5 liters) of sharps waste. Treatment involves placing disposable plastic disks with the waste and heating the waste to 375°F (190°C) for three to four hours. The waste is disinfected as it comes in contact with molten plastic flowing in and around the waste. Upon cooling, a solid plug or disk is formed which is then disposed with regular trash. The system is designed for medical and dental offices, clinics, nursing homes, and hospital departments. It is approved in various states. (Medical Innovations, P.O. Box 148, Wayland, MA 01778; Ph. 508-358-8099)

MedPro offers a small, portable, FDA-approved device called the Needlyzer for disposal of needles at the point of use. Stainless steel needles between 16 to 30 gauge are destroyed by "pyroelectric oxidation" using an arc, leaving behind granular oxidation residues. The process takes less than a second for a 20-gauge needle and any vapors pass through a three-stage filtration system. The compact device (13.5" x 5" x 4.75", 5 lbs 11 oz) has replaceable cartridges that hold the remains of 3,000 to 5,000 needles. It uses a rechargeable battery. Units cost about $895 each or lower for volume purchases. (MedPro, Inc., 817 Winchester Road, Lexington, KY 40505; Ph. 606-225-5375; Fax 606-225-5347; www.needlyzer.com; eadams@needlyzer.com)

Needle-Eater is a small device with a compact, air-tight chamber designed to destroy needles, syringes, and scalpel blades and can be used in clinics, hospital units, and medical or dental offices. It uses a high-speed cutting chamber to pulverize sharps and a disinfectant solution to decontaminate the residues. Each container can hold the remains of 75 to 150 syringes. A hardening agent is added before the waste is disposed as regular trash. (SPS Medical Equipment Corporation, 450 West First Avenue, Roselle, NJ 07203; Ph. 800-978-8006)

Sharpx Needle Destruction Unit is a small device designed to destroy 19-27 gauge hypodermic needles in a few seconds. It uses a 7.2 VDC high capacity rechargeable NiCad battery with a 60-minute fast charge. The device is 8.25" x 4" x 4" H and weighs 2 pounds. It can be used as a portable unit or mounted in a permanent location. The unit should *not* be used in any potentially explosive environment or where flammable gases and liquids are stored or used, such as operating suites or emergency rooms. (Biomedical Disposal, Inc., 3690 Holcomb Bridge Road, Norcross, GA 30092; Ph. 888-393-9595; Fax 770-300-9599; www.biodisposal.com)

NOTES

1. Based on vendor website, brochures and technical data provided by BioSterile Technology from 1994 to 2000, and personal communications with Gary Bowser.
2. Based on technical data provided by the university's Laboratories for Pollution Control Technologies from 1997 to 2000, newspaper clippings, data provided by Dean Brown, site evaluation of the unit at the University of Miami-Coral Gables, and personal communications with Thomas Waite and Charles Kurucz.
3. Based on personal communications and materials provided by Michael Chelette in 1999.

Chapter 10

Factors to Consider in Selecting a Non-incineration Technology

Determining the best technology or combination of technologies for a particular facility depends on many site-specific factors including the amount and composition of waste generated, available space, regulatory approval, public acceptance, and cost. Some key factors to consider are listed in Table 10-1 and discussed in this chapter. A comparison of technologies is provided in Table 10-5 at the end of the chapter.

TABLE 10-1. FACTORS TO CONSIDER IN SELECTING A TECHNOLOGY

- Throughput capacity
- Types of waste treated
- Microbial inactivation efficacy
- Environmental emissions and waste residues
- Regulatory acceptance
- Space requirements
- Utility and other installation requirements
- Reduction of waste volume and mass
- Occupational safety and health
- Noise and odor
- Automation
- Reliability
- Level of commercialization
- Technology manufacturer/vendor background
- Cost
- Community and staff acceptance

Throughput Capacity

Having determined the rate of waste generation for different waste streams and having implemented a vigorous waste minimization plan, the health care facility is now in a position to select a non-incineration treatment technology whose throughput rates are appropriate for the types and amount of medical waste to be treated. When matching throughput capacities with waste generation rates, the facility should take into account future anticipated growth and variabilities in waste generation. Some technologies may have a minimum feed rate to operate well or cost-effectively; technologies have a maximum design feed rate. Facilities should determine if their range of waste generation variability during the expected life of the equipment falls within the minimum and maximum feed rates of that equipment. The facility may also look at using a combination of technologies (e.g., a large technology for most of the waste, a small technology to handle difficult waste streams at the point of generation). Keep in mind that the throughput rates cited by technology vendors are approximate and that actual throughput rates depend on waste densities and other factors.

Types of Waste Treated

Broad categories are used to describe the types of waste that a technology can handle, generally based on manufacturers' recommendations. After determining what goes in a red bag, facilities should make sure that the selected technology can indeed treat each waste category from the perspective of mechanical destruction, microbial inactivation, emissions, regulatory acceptance, and safety.

When sizing the equipment, one must consider the types of waste that the technology can treat by subtracting the portion of the waste stream that the technology cannot handle (or is not permitted to handle due to regulations) from the regulated medical waste stream. The facility will have to make other arrangements for those excluded wastes. The cost of treating the excluded waste should be accounted for when comparing overall costs of alternatives.

The use of monitoring equipment, such as devices to detect low-level radioactive waste, can help keep specific waste streams out. Some technology vendors offer monitoring devices to exclude unwanted materials from the input stream. Others design their equipment to be able to interface with such devices.

Microbial Inactivation Efficacy

The main purpose for the treatment technology is to decontaminate waste by destroying pathogens. Facilities should make certain that the technology can meet state criteria for disinfection. Many states require approval of alternative technologies based on microbiological inactivation efficacy. A consortium of state regulatory agencies called the State and Territorial Association on Alternative Treatment Technologies (STAATT) met in

1994 and 1998 to develop consensus criteria for medical waste treatment efficacy. The first STAATT meeting came up with the following definitions of the levels of microbial inactivation:

Level I Inactivation of vegetative bacteria, fungi, and lipophilic viruses at a 6 Log 10 reduction or greater

Level II Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, and mycobacteria at a 6 Log 10 reduction or greater

Level III* Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, and mycobacteria at a 6 Log 10 reduction or greater; and inactivation of *B. stearothermophilus* spores and *B. subtilis* spores at a 4 Log 10 reduction or greater

Level IV Inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, and mycobacteria, and *B. stearothermophilus* spores at a 6 Log 10 reduction or greater

* Level III was selected as the recommended minimum criteria by STAATT.

A 6 Log 10 reduction (or a 10^6 kill) is equivalent to a one millionth survival probability in a microbial population or a 99.9999 percent reduction of the given microorganism as a result of the treatment process. Selected pathogen surrogates representing the above-mentioned microorganisms are used in testing. The following representative biological indicators were recommended at the second STAATT meeting ("ATCC" refers to the American Type Culture Collection):

Mycobacteria (6 Log 10 reduction):

- *Mycobacterium phlei*
- *Mycobacterium bovis* (BCG) (ATCC 35743)

Bacterial Spores (4 Log 10 reduction):

- *B. stearothermophilus* (ATCC 7953)
- *B. subtilis* (ATCC 19659)

In 2000, Underwriters Laboratories (UL) began work on a consensus standard for alternative treatment technologies which includes efficacy. Technology vendors should be able to provide documentation showing that their technology can meet applicable state regulations if any, the above criteria, and the efficacy requirements of UL 2334.[1] If no documentation is available, the facility should request that efficacy testing be conducted using an independent, qualified laboratory.

Environmental Emissions and Waste Residues

Facilities should consider discharges or emissions (including fugitive emissions) to all possible environmental media – workplace air, outside air, waste residues, wastewater, landfills, etc. – and select technologies with the least impact on the environment. Facilities may be able to obtain data from state regulators regarding any past permit violations by others using the technology.

For air emissions, facilities should obtain copies of tests of the exhaust gas and other air emissions. One should also consider the environmental impacts of utility usage especially for technologies that consume large amounts of electricity or water. High-heat thermal treatment systems should be able to show that their emissions meet the EPA limits under the 1997 "Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Hospital / Medical / Infectious Waste Incinerators." Table 10-2 shows the emission limits set on nine criteria pollutants under the rule for new incinerators. (Not shown are separate emission limits for existing incinerators.)

The EPA compliance schedule is as follows: State plans were due September 1998; state plans were approved by March 1999; the federal plan for states without approved plans was due by September 1999; and the compliance window is from March 2000 to September 2002. All existing incinerators must be in full compliance by the middle of September 2002.

In addition to the legally required EPA limits, the Natural Resources Defense Council calculated much more stringent limits for emissions from medical waste incinerators. These alternative emission limits are shown in Table 10-3 for comparison.

The EPA proposed (but did not promulgate) performance standards for medical waste pyrolysis units. These proposed standards were not incorporated into the final rule. Since pyrolysis units have generally cleaner emissions than incinerators, the proposed emission limits are somewhat more stringent, as shown in Table 10-4. Emissions from pyrolysis systems could be compared with these proposed limits. Facilities could request pyrolysis technology vendors to provide documentation showing that their technologies can meet the proposed emission limits below.

All liquid discharges should meet requirements set by the local publicly owned treatment works (POTW) or National Pollutant Discharge Elimination System (NPDES) permits, if discharging directly into surface streams.

Solid waste residues should pass the EPA's toxicity characteristic leachate procedure (TCLP) in order to be disposed at a municipal solid waste landfill. Sharps waste should be made unusable during the treatment process.

TABLE 10-2. EPA EMISSION LIMITS FOR NEW HOSPITAL/MEDICAL/INFECTIOUS WASTE INCINERATORS

POLLUTANT	EMISSION LIMITS		
	Small	Medium	Large
Particulate Matter	69 mg/dscm	34 mg/dscm	34 mg/dscm
Carbon Monoxide	40 ppmv	40 ppmv	40 ppmv
Dioxins/Furans	125 ng/dscm total or 2.3 ng/dscm TEQ	25 ng/dscm total or 0.6 ng/dscm TEQ	25 ng/dscm total or 0.6 ng/dscm TEQ\
Hydrogen Chloride	15 ppmv or 99% reduction	15 ppmv or 99% reduction	15 ppmv or 99% reduction
Sulfur Dioxide	55 ppmv	55 ppmv	55 ppmv
Nitrogen Oxides	250 ppmv	250 ppmv	250 ppmv
Lead	1.2 mg/dscm or 70% reduction	0.07 mg/dscm or 98% reduction	0.07 mg/dscm or 98% reduction
Cadmium	0.16 mg/dscm or 65% reduction	0.04 mg/dscm or 90% reduction	0.04 mg/dscm or 90% reduction
Mercury	0.55 mg/dscm or 85% reduction	0.55 mg/dscm or 85% reduction	0.55 mg/dscm or 85% reduction

mg = milligrams dscm = dry standard cubic meter ppmv = parts per million by volume ng = nanograms TEQ = toxic equivalent
Capacities: small=less than or equal to 200 lbs/hr; medium=greater than 200 lbs/hr to 500 lbs/hr; large=greater than 500 lbs/hr.
In addition, new incinerators are subject to a 5% visible emission limit for fugitive emissions generated during ash handling and a 10% stack opacity limit.

TABLE 10-3. NRDC'S SUGGESTED EMISSION LIMITS FOR MEDICAL WASTE INCINERATORS

POLLUTANT	NRDC EMISSION LIMITS	
	New Sources	Existing Sources
Particulate Matter	0.0006 gr/dscf	0.0007 gr/dscf
Carbon Monoxide	0 ppmv	0.17 ppmv
Dioxins/Furans	0.0078 ng/dscm TEQ	0.012 ng/dscm TEQ
Hydrochloric Acid	0.05 ppmv	0.1 ppmv
Sulfur Dioxide	0.68 ppmv	0.85 ppmv
Nitrogen Oxides	39.5 ppmv	42.3 ppmv
Lead	0.001 mg/dscm	0.002 mg/dscm
Cadmium	0.0004 mg/dscm	0.0007 mg/dscm
Mercury	0.002 mg/dscm	0.003 mg/dscm

dscf = dry standard cubic feet gr = grains mg = milligrams

TABLE 10-4. PROPOSED EMISSION LIMITS FOR PYROLYSIS UNITS

POLLUTANT	EMISSION LIMITS (7% oxygen, dry basis)
Particulate Matter	34 mg/dscm
Carbon Monoxide	40 ppmv
Dioxins/Furans	25 ng/dscm total or 0.6 ng/dscm TEQ
Hydrogen Chloride	15 ppmv or 99% reduction
Sulfur Dioxide	55 ppmv
Nitrogen Oxides	250 ppmv
Lead	0.05 mg/dscm
Cadmium	0.04 mg/dscm
Mercury	0.23 mg/dscm

Some have argued that treated waste must be made unrecognizable for aesthetic reasons, as an added indication that the waste has been treated, and because rendering the waste unrecognizable usually entails a reduction in waste volume.

Regulatory Acceptance

All states accept autoclave steam treatment systems for medical waste treatment. (Some states explicitly prohibit chemotherapy waste from being treated in an autoclave.) For other types of processes, including some of the so-called advanced autoclaves, some states have regulations requiring alternative technologies be approved. Other states have no such approval procedures but may accept a technology on a case-by-case basis or for a site-specific use. Many vendors have already gained formal approvals or letters of acceptance for their technologies in multiple states. Due to the cost of testing, however, technology vendors often wait for potential customers before submitting applications for approval in a state. In some states, approvals may be required from more than one agency (e.g., one dealing with microbial inactivation and another with air emissions). Facilities should check with their state regulators to see if the technology is approved or accepted. Some states may accept test results submitted to other states and streamline their approval process. Table 10-5 shows the results of a 1998 state regulatory survey by *Waste Age*[2]. *[Note: Since regulations change frequently, readers should check with their state regulators for the latest requirements.]*

As has been noted, not all states require that medical waste be rendered unrecognizable. Some states only require that human tissue be made unrecognizable. Many states, however, require that sharps be broken (or ground up), made unusable, and/or packaged in puncture-resistant containers.

A few states prescribe specific treatment processes for certain types of waste. For example, some states may require that chemotherapy waste can only be incinerated or that anatomical parts can only be incinerated or interred. Facilities should check with their regulators to determine if certain waste streams cannot be treated in a non-incineration technology for legal reasons.

Space Requirements

Space is usually a premium at health care institutions. The space needed to operate a technology should fit the available space in the facility. That space is not only the footprint and height of the equipment but should also include additional space needed for opening waste entry doors, access to control panels, space for hydraulic lifts, conveyors, moving bins, storage areas, etc. Some non-incineration technologies have compact designs but others require a lot of room. Other possibilities include using mobile or portable units, trailer-mounted units, underground installations, or all-weather enclosed shelters at an outdoor site.

Utility and Other Installation Requirements

Some technologies only need an electrical outlet to operate; others require steam, compressed air, natural gas, drains, ventilation, etc. Concrete pads, access paths, curb cuts, and other site preparations may be needed. The

TABLE 10-4. PROPOSED EMISSION LIMITS FOR PYROLYSIS UNITS

STATE	Specific medical waste regulations?	Approved alternative technologies?	Landfilling of untreated waste allowed?	Medical waste must be rendered unrecognizable?
Alabama	Y	Y	N	Y*
Alaska	Y	N	N	N
Arizona	N	N	Y	N
Arkansas	Y	N	N	Y
California	Y	Y	N	N
Colorado	Y	N	Y	N
Connecticut	Y	Y	N	Y
Delaware	Y	Y	N	Y
D.C.	N	N	N	N
Florida	Y	Y	N	N*
Georgia	Y	Y	Y	N
Hawaii	Y	N	N	N
Idaho	N	N	Y	N
Illinois	Y	Y	N	N
Indiana	Y	N	N	N
Iowa	N	Y	N	Y
Kansas	Y	Y	Y	N
Kentucky	Y	N	-	-
Louisiana	Y	Y	N	Y*
Maine	Y	N	N	Y
Maryland	Y	Y	N	Y*
Massachusetts	Y	Y	N	N
Michigan	Y	Y	Y	Y*
Minnesota	Y	Y	N	N
Mississippi	N	N	N	N
Missouri	Y	N	N	N
Montana	Y	Y	N	Y*
Nebraska	Y	Y	Y*	-
Nevada	Y	N	Y	N
New Hampshire	Y	N	N	N
New Jersey	Y	Y	N	Y
New Mexico	Y	Y	N	N
New York	Y	Y	N	N
North Carolina	Y	Y	Y	N
North Dakota	Y	N	N	N
Ohio	Y	Y	Y	N
Oklahoma	Y	N	N	N
Oregon	Y	Y	Y*	N
Pennsylvania	Y	Y	N	N
Rhode Island	Y	Y	N	Y
South Carolina	Y	Y	Y	N
South Dakota	Y	N	N	N
Tennessee	N	N	N	Y
Texas	Y	Y	N	Y
Utah	Y	N	Y	N
Vermont	Y	N	N	N
Virginia	Y	Y	N	Y
Washington	N	N	Y	N
West Virginia	Y	Y	N	N
Wisconsin	Y	Y	N	Y
Wyoming	N	N	Y	N

Y = yes, N = no, - = not available, * some types, sharps

IS INCINERATION ESSENTIAL FOR CERTAIN TYPES OF WASTE?

Some states require that chemotherapeutic waste and anatomical remains should be incinerated. Chapter 7 shows that high-heat thermal technologies, which operate at or above incinerator temperatures, can handle the same waste streams as those treated in a medical waste incinerator. Tissue and animal wastes can also be treated in at least one chemical treatment system (alkaline hydrolysis). While it is technically feasible to treat body parts in other treatment technologies, there may be ethical, legal, cultural, aesthetic, and other constraints. Interment (burial) is another option for large anatomical remains.

Even though only eight chemotherapy drugs (Chlorambucil, Cyclophosphamide, Daunomycin, Melphalan, Mitomycin C, Streptozotocin, Chlornaphazin, and Uracil Mustard) are specifically listed as hazardous waste under RCRA, all chemotherapy agents should be treated as toxic waste[3]. Thus, all bulk chemotherapy waste must be disposed of as hazardous waste and can be sent to a hazardous waste landfill except for a few specific chemotherapy agents that have land disposal restrictions under RCRA. Technically, however, chemotherapy waste can be destroyed by a chemical treatment technology—namely, alkaline hydrolysis—and also by high-heat thermal systems such as pyrolysis-oxidation or plasma pyrolysis. However, federal or state regulations may limit treatment options.

In 1987, an EPA policy letter clarified that waste contaminated with trace residues of chemotherapy agents would be considered non-hazardous waste if it meets the "empty container" criteria[4]. Therefore, except where prohibited by state or local regulations, trace-contaminated chemotherapy waste may be treated in low-temperature thermal treatment systems such as microwave units. In an autoclave, some of the less stable compounds may begin to decompose to form small amounts of toxic byproducts. Disposal in this manner of trace-contaminated chemotherapy waste may result in some occupational exposures to hospital staff, waste collectors, or landfill workers, and could contaminate the landfill. Treatment in pyrolysis and other alternative high-heat technologies would result in pollutants but most likely at lower levels than with incineration. When treating trace-contaminated chemo waste using hot alkaline hydrolysis technology, antineoplastic agents are decomposed into biodegradable byproducts, while plastics, metals, cloth, etc. will be disinfected but remain basically unchanged. In contrast, incineration of chemotherapy waste may result in occupational exposures to waste collectors and incinerator operators, and will generate NOx, HCl, and possibly dioxins, furans, and other toxic pollutants.

In summary, pathological and chemotherapy wastes can be treated using non-incineration technologies, although legal and other considerations may limit treatment options. In principle, incineration is not essential, as there are non-incineration alternatives that technically can handle all portions of the medical waste stream.

location may or may not be equipped with a loading dock, storage space, security fence, roll-off containers, etc. Not all facilities will have these utility services and other infrastructure available at the selected site. Some vendors include the cost of installation in the equipment price but facilities will have to provide some basic services. Processes that do not alter the physical characteristics of waste will need ancillary equipment such as shredders and compactors to reduce waste volume and make waste unrecognizable.

Reduction of Waste Volume and Mass

Volume and/or mass reduction is another important factor since facilities will have to pay by volume or mass for hauling the treated waste and disposing at a landfill. The number of solid waste landfills has declined from about 20,000 in the early 1970s to less than 3,000 in the mid-1990s.[5] Although many states still have sufficient landfill capacities, others have less than five or ten years of disposal capacity left. Diminishing landfill capacities could eventually drive up the cost of land disposal which has increased an average of seven percent annually. High-heat thermal technologies offer the highest levels of volume and mass reduction. Other technologies may require an added shredder or compactor to reduce waste volume. By selecting a technology that achieves a high reduction in waste volume, facilities can help ameliorate the problem of diminishing landfill capacities and minimize environmental impact.

Occupational Safety and Health

Issues of occupational safety and health were discussed in Chapter 2. When selecting a treatment technology, facilities should consider potential worker exposure to: hot

surfaces, ionizing and non-ionizing radiation, chemicals released in the workspace, sharps that may fall out during conveying, pathogens from the waste that are aerosolized during shredding, blood splatter, etc. It may be possible to obtain the safety record of a technology from facilities that have used the technology for some time.

Facilities should find out from technology manufacturers how their equipment will react if potentially dangerous materials, such as flammable liquids, aerosol cans, large metal parts, low-level radioactive waste, etc., are fed into the equipment. With high heat systems, large amounts of aqueous liquids may result in the rapid release of steam and a sudden rise in pressure. Mixtures of certain chemicals may react to produce toxic gases: for example, concentrated acid or ammonia react with sodium hypochlorite to form chlorine gas or chloramine gas, respectively. Facilities should have emergency procedures in place and take preventive measures.

In the event of an equipment breakdown, the technology should have some way of protecting workers who may need to access internal parts of the equipment. Some technologies have a way of injecting chemical disinfectants on untreated waste and internal surfaces in these situations. Others have safety interlocks that prevent workers from opening a treatment chamber door if the treatment cycle has been interrupted.

Underwriters Laboratories is developing standards (UL 2334) dealing with risk of fire, electric shock, and mechanical hazards, among others. Non-incineration technologies should be able to meet those standards.

Noise and Odor

Some vendors represent their technologies as noiseless and odor-free. The best way to evaluate this is to observe the technology during actual operation, either at the manufacturing facility or preferably, at an installation in another health care facility. Reducing noise and noxious odors are important aspects of occupational health and community relations.

Automation (or Ease of Use) and Operator Training

A technology should be automated to minimize operator errors while allowing efficient and easy control of the process, safety interlocks, diagnostics, remote monitoring, alarms, and automatic documentation to meet record keeping requirements. Most non-incineration technologies are also designed for ease of use and minimal operator time. Usually, the most labor-intensive task is introducing waste into the equipment. It is also a source of occupational injuries (e.g., back problems, needle-sticks). Many technologies now include automatic feed assemblies such as cart lifters or bin dumpers to eliminate handling of red bags by workers.

When selecting a technology, the level of required skills and necessary training of the operator should be considered. Vendors generally offer operator training when a new system is installed; the facility may need to arrange for ongoing training and education. Operator training should include a basic understanding of the systems, standard operating procedures, occupational safety and personal protection equipment, recordkeeping, identifying waste that should not be treated in the technology, recognizing technical problems, dealing with unusual conditions, periodic maintenance schedules, emergency procedures, and contingency plans. Facilities should document operator training and qualification.

Reliability

Reliability of equipment can be determined from past maintenance records (these may or may not be available for new technologies). Some vendors offer remote monitoring and diagnostics capabilities. High-maintenance items include major moving parts such as shredders, grinders, and feed systems, and parts that are subjected to high thermal stresses such as refractories. Facilities may be able to review maintenance records from other facilities that have used the equipment. For new technologies, facilities should find out how long the technology has been in full, continuous operation without having any problems.

Facilities should check to see if vendors are well-stocked with spare parts and staffed with technical people who can respond quickly to queries or provide urgent repair services. The availability of technical support is important, especially for newly commercialized technologies that may not have a long track record of operation. For technologies that have been in operation long enough, one may be able to obtain good estimates of equipment life.

Level of Commercialization

Facilities should request a list of permanent installations and contact information for those sites. Technologies that are fully commercialized may have an extensive network of distributors and technical service centers. They may be able to respond quickly to urgent needs. These are some of the obvious advantages of a fully commercialized system. On the other hand, it may be possible to get major reductions in capital costs from vendors whose technologies are in their initial stages of commercialization. Some vendors of new technologies may be willing to offer large discounts in exchange for being able to demonstrate

TABLE 10-6. SOME COMPARISONS OF SELECTED NON-INCINERATION TREATMENT TECHNOLOGIES

TECHNOLOGY/VENDORS	APPROXIMATE CAPACITY (LBS/HR)	TYPES OF WASTE TREATED *	APPROXIMATE VOLUME. REDUCTION (%)	STAGE OF COMMMERCIALZATION.***
LOW-HEAT THERMAL PROCESSES+				
Bondtech (Somerset, KY)	250-6000	CS, S, I, L, SW, LB	0 **	C
Environmental Techtonics Corp. (Southampton, PA)	4000 lb/day +	CS, S, I, L, SW, LB	0 **	C
Mark-Costello (Carson, CA)	225-3000	CS, S, I, L, SW, LB	0 **	C
Sierra Industries (Santa Ana, CA)	200-750	CS, S, I, L, SW, LB	0 **	C
SteriTech (Bloomington, IN)	18-115	CS, S, I, L, SW, LB	0 **	C-n
Tuttnauer (Ronkonkoma, NY)	Up to 1500	CS, S, I, L, SW, LB	0 **	C
San-I-Pak (Tracy, CA)	25-2240	CS, S, I, L, SW, B	75-85	C
Tempico (Madisonville, LA)	300-750+	CS, S, I, L, SW, B	80	C
Sterile Technologies Inc. (West Chester, PA)	600-4000	CS, S, I, L, SW, B	80-90	C
Antaeus Group (Hunt Valley, MD)	150	CS, S, I, L, SW, B	80	C-n
Ecolotec (Union Grove, AL)	300	CS, S, I, L, SW, B	N/a	C-n
Hydroclave Systems Corp. (Kingston, Ontario, Can.)	200-2000	CS, S, I, L, SW, B	N/a	C
Aegis Bio-Systems (Edmond, OK)	1500	CS, S, I, L, SW, B	80	C-n
LogMed (Erdwich ZerkleinerungsSysteme GmbH	N/a	N/a	N/a	N/a
Sanitec (West Caldwell, NJ)	220-550	CS, S, I, L, SW, B, TCT+	80	C
Sintion/CMB (Austria)	78	CS, S, I, L, SW, LB	N/a	N/a
Stericycle (Lake Forest, IL)	1000-6000	CS, S, I, L, SW, B	N/a	C
KC MediWaste (Dallas, TX)	200	CS, S, I, L, SW, B	80	C-n
Demolizer	1 gal/2.5 hr	CS, S, I, L, SW, LB	0	C
MEDIUM-HEAT THERMAL PROCESSES+				
Environmental Waste International (Ajax, Ontario)	110-180	CS, S, I, L, SW, B, P	80	C-n
Changing World Technologies (West Hempstead, NY)	7.5-15 tons/day	N/a	N/a	D
HIGH-HEAT THERMAL PROCESSES				
Bio-Oxidation/Oxidation Techn. (Annapolis, MD)	100-1500	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	95-98	C
DayStar/Prometron (Tokyo, Japan)	200	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	N/a	D
Electro-Pyrolysis, Inc. (Wayne, PA)	750	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	90	D
HI Disposal Systems (Indianapolis, IN)	3000	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	95-98	D
Integrated Environmental Technologies (Richland, WA)	0.5-10 tons/day	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	95-98	C-n
MSE Technology Applications (Butte, MT)	Up to 350	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	N/a	D
Plasma Pyrolysis Systems (Stuyvesant Falls, NY)	360	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	N/a	D
Startech Environmental Corp. (Wilton, CT)	4-100 tons/day	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	98	C-n

TECHNOLOGY/VENDORS	APPROXIMATE CAPACITY (LBS/HR)	TYPES OF WASTE TREATED *	APPROXIMATE VOLUME. REDUCTION (%)	STAGE OF COMMMERCIALZATION.***
HIGH-HEAT THERMAL PROCESSES (CONTINUED)				
Unitel Technologies (Mt. Prospect, IL)	N/a	N/a	N/a	N/a
Vance IDS/Bio Arc (Largo, FL)	400	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	95-98	C-n
Vanguard Research Inc. (Lorton, VA)	N/a	N/a	N/a	N/a
Vanish Technologies/LFR (Raritan, NJ)	280	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	90	D
Anara Group (Las Vegas, NV)	5-100 tons/day	N/a	N/a	N/a
NCE Corporation (Carrollton, TX)	200	CS, S, I, L, SW, B, P, A, BCT+, SS, PH	95-99	C-n
CHEMICAL PROCESSES				
Circle Medical Products (Indianapolis, IN)	250-3000	CS, S, I, L, SW, B	80	C
MedWaste Technologies Corp. (Houston, TX)	N/a	CS, S, I, L, SW, B	N/a	C
Encore/Medical Compliance (El Paso, TX)	2500-3000	CS, S, I, L, SW, B	N/a	C
Lynntech (College Station, TX)	220-518 lbs/cyc	CS, S, I, L, SW, B	N/a	D
MeDETOX/Delphi Research (Albuquerque, NM)	N/a	N/a	N/a	D
MCM Environmental Technologies (Gilboa, Israel)	20 gal/15 min	N/a	N/a	N/a
Positive Impact Waste Solutions (Pearland, TX)	up to 2000	CS, S, I, L, SW, LB	80-90	D
Premier Medical Technology (Houston, TX)	600-900	CS, S, I, L, SW, LB	80-90	D
Ecocycle 10/STERIS Corp. (Mentor, OH)	8 lbs/10 min	CS, S, I, L, SW, LB	80	C
WR² (Indianapolis, IN)	50-7000 lbs/cyc	CS, S, I, L, SW, B, P, A, TCT	N/a	C
IRRADIATION PROCESSES				
BioSterile Technology (Fort Wayne, IN)	400-550	CS, S, I, L, SW, B, P, A	0**	C-n
U. Miami E-Beam (Coral Gables, FL)	400	CS, S, I, L, SW, B, P, A	85	D
BIOLOGICAL PROCESSES				
Bio Conversion Technologies, Inc. (Norcross, GA)	10 tons/day	N/a	N/a	D

Legend: CS=cultures and stocks; S=sharps; I=isolation waste; L=lab wastes excluding chemicals; SW=soft wastes such as contaminated bandages and gloves; LB=limited amounts of blood and body fluids; B=bulk blood and body fluids; P=pathological waste including anatomical parts; A=animal waste; TCT=trace-contaminated chemotherapeutic waste; BCT=bulk contaminated and/or trace-contaminated chemotherapy waste—note that certain specific bulk chemotherapy wastes have land disposal restrictions under RCRA; SS=spent solvents and chemical waste; PH=pharmaceutical waste

* Regulations and specific designs may differ on the types of waste that may be treated with these technologies. Treatment of some wastes may require additional permits. Technically, it may be possible to treat pathological waste in some low-heat thermal or chemical treatment technologies as long as treatment parameters are adjusted to ensure that large anatomical parts are properly disinfected. However, legal, ethical, cultural, aesthetic, and other considerations may preclude treatment of pathological waste with these technologies. Facilities should check with vendors and regulators.

** Volume reduction without optional shredder or other mechanical device; an auxiliary shredder would reduce waste volume by about 70-80%.

*** Stage of commercialization; Legend: C=fully commercialized; C-n=newly commercialized; D=developing technology or nearly commercialized

+ It may be legally acceptable to treat trace-contaminated chemotherapy waste with various technologies although some state and local regulations may prohibit such treatment; see also discussion under "Is Incineration Essential for Certain Types of Waste?" in this chapter. Federal regulations have land disposal restrictions for certain specific chemotherapy agents (U-listed hazardous waste). Facilities should check with regulators and vendors.

their technology at a health care facility. Obviously, there are risks involved in being the first to use a technology with little or no track record.

Technology Manufacturer/ Vendor-Background

Facilities could benefit from knowing how long a technology manufacturer and/or vendor has been in business, what their financial status is (i.e., are they financially stable?), the backgrounds of key officers of the company, whether or not they have been cited for environmental or other violations, and any financial or legal liabilities. For new technologies, facilities may want to find out how the company plans to market the technology, how well they are capitalized, whether or not they can fill orders in a reasonable time, etc. Facilities should also find out if a technology developer is involved in legal disputes of intellectual property rights with other parties in relation to a new technology.

Cost

Health care institutions are under pressure to cut costs. Therefore, after drawing up a list of technologies that meet the site-specific requirements of a facility, a comparison can be made to determine the most cost-effective option. Decision-makers may wish to determine whether non-incineration technologies would save money in the long run compared to upgrading an existing incinerator, constructing a new incinerator that meets EPA's New Source Performance Standards, or contracting with a hauler to transport and treat medical waste at an off-site regional facility. The economics of treatment technologies are discussed in the next chapter.

Community and Staff Acceptance

Educating the staff about the pros and cons of non-incineration technology options and involving them in the selection process are important in order to gain support for a new technology. Notwithstanding regulatory approval of a technology, siting of a new system may be hampered by a lack of public acceptance especially if the site is located near residences, schools, and sensitive populations. Treatment processes with which the public is familiar, such as microwave or steam systems, may be accepted by the community more readily than lesser known technologies such as plasma and electron beam technologies. A program to inform and engage the community in the selection of an alternative technology, allowing the community an opportunity to provide input into the decision-making process, would result in greater community satisfaction and improved standing of the health care facility as an environmental leader in the community.

Some Comparisons

Table 10-6 provides some comparisons of non-incineration technologies. With regards to the types of waste treated, regulations and specific designs may differ on the types of waste that may be treated with these technologies. Treatment of some wastes may require additional permits. Facilities should check with vendors for the latest and most accurate information.

NOTES

1. Underwriters Laboratories. "Standard for Alternative Treatment Technologies for the Disposal of Medical Waste." Draft ANSI/UL Standard, UL-2334 (Research Triangle Park, NC: Underwriters Laboratories, 2000); www.ul.com/eph/medwaste.htm
2. "Medical Waste: Still Healthy After All These Years," Dee NaQuin, *Waste Age* (Environmental Industry Associations, Washington, DC), Vol. 29, No. 7, July 1998.
3. P. Vaccari et al., "Disposal of antineoplastic wastes at the National Institutes of Health," Am J Hosp Pharm, 41, 87 (January 1984); "Hazardous Drug Waste Management," Chapter 12 in W.L. Turnberg, *Biohazardous Waste: Risk Assessment, Policy and Management*, (New York, NY: John Wiley & Sons, Inc., 1996).
4. OSWER Directive 9441.1987(45) (policy directive from J. Sales, Chief, Regulation Development Section, EPA), U.S. Environmental Protection Agency, June 16, 1987; cited in W. L. Turnberg, loc. cit. "Empty containers" are containers from which chemotherapy agents have been removed and no more than 1 inch of residue or no more than 3% by weight of residue remains in the container. The EPA recommends that materials such as vials, syringes, gloves, etc. contaminated with these chemicals not be handled after use to minimize exposure.
5. E.W. Repa and A. Blakey, "Municipal Solid Waste Disposal Trends: 1996 Update," *Waste Age* (Environmental Industry Associations), January 1996.

Chapter 11

Economics of Treatment Technologies: Comparing Treatment Options

This chapter discusses the economics of non-incineration technologies including suggestions on evaluating and comparing costs of alternatives and the costs of incinerator upgrades and hauling.

The following are common techniques used for comparative analyses of economic options:

Annual Cash Flow Projections

Cash flows are the expenditures made and revenues received during the lifetime of a technology. By computing annual expenditures and revenues, a year-by-year cash flow projection is established. Capital costs (including site preparation and installation) may be accounted for by assuming a fixed interest rate and amortizing the capital cost for the lifetime of the technology. Non-incineration technologies could be compared using the same interest rate and, in the case of unequal equipment lives, assuming that one adds a new identical technology at the end of the useful life for a shorter-lived technology. To calculate the fixed annual payment (i.e., amount of the annuity) for the amortized capital cost, the following well-known equation is used if annuity tables are not available:

$$\text{Annuity} = \text{capital cost} \times (i) \times [1 / (1 - [\, 1 / (1+i)^n \,] \,) \,]$$

where i=interest rate and n=equipment life.

After adding the amortized capital costs and annual operating costs, the total costs for each year in the form of annual cash flow projections could be compared, assuming an annual inflation rate.

Net Present Value or Present Worth Method

This method uses compound interest factors to compound or discount all cash flows. Non-incineration technologies are then ranked by comparing the equivalent values at time zero of each alternative using the same interest rate and equipment lifetime. The technology with the highest present worth is the best technology from an economic standpoint.

Capitalized Cost or Life Cycle Cost Method

In this method, the present worth of a technology assuming an infinite life is computed, i.e., the capitalized cost is the initial cost plus the present value of an infinitely-lived technology. The technology with the lowest capitalized cost is the best technology from an economic standpoint.

Annual Cost or Capital Recovery Method

In this method, the equivalent uniform annual costs of technology alternatives with unequal lives are compared assuming that each alternative is continuously replaced with an identical one at the end of its useful life up to the duration of the longest-lived alternative. The technology with the lowest annual cost is the best technology from an economic standpoint.

Return on Investment Method

The return on investment (ROI) is the ratio of annual profits to original investment. This may be used to compare the savings from non-incineration technologies in relation to known costs (such as those of an existing incinerator). This method does not account for the time value of money and other factors.

These economic evaluation tools are available as software modules and spreadsheets. The comparative measures can also be compared using graphics software. In any of these methods, a sensitivity analysis can be used to determine how sensitive the results are to changes in data forecasts. This is done by changing dominant cost factors one at a time and seeing how final results compare.

COST ITEMS

Capital Costs

Total capital cost should include all direct and indirect costs related to siting and installation as well as the equipment purchase cost. Some technologies require little site preparation and installation, while others involve significant installation requirements. The following list gives examples of direct costs that need to be taken into

account. (Not all of these items necessarily apply to a given technology)

- Site preparation
- Demolition and disposal (e.g. removal of an old incinerator)
- Building (new construction or renovation)
- Foundation and supports
- Electrical service
- Piping including steam and water lines
- Heating and ventilation system
- Air compressor
- Lighting
- Sanitary sewer
- Sprinkler system
- Painting and insulation
- Handling and on-site fabrication
- Equipment purchase cost (including auxiliary devices, instrumentation, carts for transporting waste, monitoring equipment, freight, sales tax, etc.).

The following are examples of indirect costs that should be considered:

- Project management
- Engineering
- Construction fees
- Permitting
- Regulatory testing
- Professional fees (including media fees to respond to public outcry, if the community does not like the technology choice)
- Start-up
- Performance testing
- Contingencies.

There are intangible costs that cannot be quantified, such as loss of good public perception if the chosen technology is unpopular in the community or among staff.

Annual Operating Costs

Annual operating costs are costs incurred every year due to the operation of the technology during the life of the equipment. Due to inflation, the magnitude of these costs may vary, but the same kinds of costs will be incurred. Direct costs are those that are dependent on the throughput of the system, such as:

- Labor (operating and supervisory)
- Utilities:
  - *Electricity*
  - *Steam*
  - *Natural gas*
  - *Water*
  - *Compressed air*
  - *Others*
- Supplies:
  - Boxes or containers
  - Autoclavable or steam permeable bags
  - Labels
  - Others
- Consumables:
  - Chemical disinfectants
  - Electrodes or torches
  - Others
- Maintenance (scheduled and unscheduled)
- Materials
- Replacement parts (e.g; refractories, shredder blades, etc.)
- Maintenance labor
- Landfill disposal costs (including transportation and tipping fees)
- Cost of disposing wastes not treated by the technology
- Cost of treating waste during scheduled and unscheduled downtime.

Indirect costs are costs that are not proportional to throughput, such as:

- Overhead
- Administrative costs
- Insurance
- Annual regulatory permit fees
- Periodic verification or emission tests
- Taxes.

INCINERATOR UPGRADE COSTS

With respect to incineration, cost is a major factor to consider in addition to the environmental, health, and other intangible issues raised in Chapter 1. For an old existing incinerator, compliance with the EPA regula-

tion for medical waste incinerators would likely require the installation of a pollution-control device, retrofit of the secondary chamber, and the addition of monitoring equipment, as well as periodic stack testing, operator training, etc. Therefore, capital cost items include:

- Purchase and installation of a wet scrubber or other device
- Secondary chamber retrofits
- Purchase and installation of monitoring equipment.

Components of annual operating costs include:

- Annual costs related to operation of a wet scrubber or other device
- Annual costs related to the secondary chamber
- Annual cost of stack testing
- Annual cost of parametric monitoring
- Annual cost of operator training course.

In 1995-96, studies[1] were conducted by the U.S. EPA to estimate capital and annual costs for upgrading an incinerator to meet EPA requirements. It should be noted that the EPA model used average values; in some areas, the upper range of costs were as much as 70 percent higher than the national average.

Average costs were estimated (in 1995 dollars) using the equation below. The values for A and B are based on the incinerator capacity (the maximum-rated burn capacity in lbs/hr) according to three size categories of incinerator: small (less than or equal to 200 lb/hr), medium (more then 200 but less than or equal to 500 lb/hr) and large (greater than 500 lb/hr).

$$\$ = A \times (\text{incinerator capacity in lb/hr}) + B$$

The biggest capital cost item is the add-on air pollution control device. Average capital costs for a wet scrubber capable of meeting the EPA emission limits were estimated using the equation above with the following values of A and B (in 1995 dollars):

	With heat recovery boiler		Without heat recovery boiler	
Incinerator Size	A	B	A	B
Small	$103,100	112,944	$117,900	179,015
Medium	96,300	133,150	130,700	187,959
Large	80,400	201,883	145,700	234,848

The annual estimated costs for the wet scrubber are comprised of labor, maintenance, electricity, caustic chemical, sewage disposal, make-up water, and indirect costs. Using the equation above, A and B are given below (in 1995 dollars):

	With heat recovery boiler		Without heat recovery boiler	
Incinerator Size	A	B	A	B
Small	$65,400	27,357	$73,900	42,487
Medium	64,600	31,087	77,200	44,180
Large	62,800	43,846	82,500	54,267

The next major cost item is secondary chamber retrofits needed for most old incinerators to increase residence time to greater than two seconds and to improve combustion. The EPA model is given in dry standard cubic feet per minute (dscfm). Annual costs include refractory replacement, auxiliary fuel, and maintenance. Assuming a ratio of 3.165 dscfm to 1 lb/hr capacity, the equation above can be used to estimate the capital and annual costs of secondary chamber retrofits for incinerators with or without boilers using the following A and B factors (in 1995 dollars):

	Capital Cost		Annual Cost	
Incinerator Size	A	B	A	B
Small	$93,840	34,554	$27,990	6,805
Medium	93,840	34,554	28,480	6,805
Large	93,840	34,554	31,180	6,805

The costs of parametric monitoring, stack testing, and annual operator training were estimated at $16,600 for capital cost (installing equipment) and an associated annual cost of $14,264.

EXAMPLE: Based on the EPA model, upgrading an existing 550 lb/hr incinerator without a heat recovery boiler (i.e., adding a wet scrubber, retrofitting the secondary chamber, installing parametric monitoring equipment, conducting periodic tests and operator training, etc. in order to meet EPA requirements) would cost approximately (in 1995 dollars) $418,000 in capital costs plus $138,000 in annual costs over and above existing incinerator operating costs. These figures have not been adjusted for inflation. (N.B.: As mentioned above, these are average values within a range of estimates. Using the **upper** range of the model's estimates for this scenario, one gets a capital cost of $530,000 and annual costs of $183,000 in 1995 dollars.)

Improved segregation and a strong waste reduction program could reduce the required throughput rate, thus allowing the health care facility to consider a smaller non-incineration technology (less than 550 lb/hr) at lower capital and operating costs than those estimated above.

HAULING COSTS

In addition to potential liabilities, the risk of a transportation accident, legal requirements when transporting regulated medical waste, and the uncertainty of how the waste is treated and ultimately disposed of, there is also the issue of hidden costs when one considers hauling. The full costs of hauling and off-site treatment are not limited to the price set by the hauler. The following are some of the hidden capital costs related to hauling:

- Siting and construction of storage and loading areas including ramps and loading docks
- Other infrastructure (fences, enclosures, refrigeration of storage area, etc.)
- Transport containers
- Personnel protection equipment, spill kits.

Additionally, annual costs that may not be included in the hauling price are:

- Labor (related to packing, labeling, storage, loading, and waste tracking/documentation)
- Labor (related to security, maintenance of storage areas, and pest management)
- Supplies (boxes, biohazard labels, packing tape, etc.)
- Maintenance materials (for cleaning of the storage area)
- Liability insurance and other fees
- Transportation charges and landfill disposal fees
- Annual refrigeration costs
- Costs related to disposal of waste not accepted by the hauler
- Penalty fees (for containers not meeting the hauler's specifications).

Some cost items, such as penalty fees, may turn out to be quite significant. These and any other costs not included in the hauling price should be taken into account when evaluating options from an economic perspective. Unfortunately, other issues, such as potential liability and uncertainty regarding how the waste is ultimately disposed of, cannot be assigned a dollar value.

COSTS OF NON-INCINERATION TECHNOLOGIES

The cost of non-incineration technologies vary widely. In general, the capital cost of steam-based technologies are lower than those of high heat thermal systems. Some technologies, such as the Bio-Oxidizer and plasma-based technologies, may be more cost-effective when scaled up for use in regional treatment centers. Approximate capital costs, where available, are shown in Table 11-1 for various non-incineration technologies.

Most vendors will quote an estimated cost-per-pound for their technology. Not surprisingly, these per-pound costs are often computed using assumptions and scenarios that present the technology in the best light in comparison with other technologies. Facilities should determine what cost items are included in the vendor's figure and what assumptions were used to compute it.

The best way to compare annual per-pound costs is to apply one of the techniques discussed above, such as an annual cash flow comparison. Effort should be made to get an estimate of the full costs of the technology by accounting for all possible cost items. It is important to compare "apples with apples" by using identical or analogous scenarios when conducting comparative economic analyses of non-incineration technologies. In general, electron beam technologies seem to have the lowest operating cost (despite their moderate to high capital costs), followed perhaps by low-heat thermal and chemical technologies. As pointed out earlier, the high capital cost of one technology may be compensated by its very low annual operating costs, while the low purchase price of another technology may be offset by its high operating costs or by high installation costs. One method of comparison is to compute total costs per pound, whereby the total cost is the sum of installed capital costs amortized for the life of the technology plus annual operating costs. The amortized capital costs of each technology should be based on identical interest rates.

Some of these calculations can be automatically done using computer spreadsheets. For example, the EPRI Healthcare Initiative has developed a proprietary software, Medwaste Alternative Technologies Evaluation Systems (MATES), available to Healthcare Initiative members, that compares annual cash flow projections of incineration and non-incineration technologies.[2]

OPTIONS FOR ACQUISITION

There are various ways of acquiring a new technology. Many health care organizations require competitive bidding for procuring items above a certain cost threshold. The facility must first develop technical specifications and other bidding documents that are then sent out. Bidders respond by submitting complete and detailed design and engineering submittals as well as price bids. In a two-phase bidding process used for large complex projects, an evaluation team first assesses unpriced technical offers;

TABLE 11-1. COSTS OF SELECTED NON-INCINERATION TREATMENT TECHNOLOGIES FOR MEDICAL WASTE

NON-INCINERATION TECHNOLOGIES	TECHNOLOGY VENDORS	APPROX. CAPITAL COST ($)
LOW HEAT THERMAL PROCESSES		
Autoclave or Retort	Bondtech (Somerset, KY)	90,000-175,000
Autoclave or Retort	Environmental Techtonics Corp. (Southampton, PA)	N/a
Autoclave or Retort	Mark-Costello (Carson, CA)	26,000-41,000
Autoclave or Retort	Sierra Industries (Santa Ana, CA)	N/a
Autoclave or Retort	SteriTech (Bloomington, IN)	N/a
Autoclave or Retort	Tuttnauer (Ronkonkoma, NY)	100,000-200,000
Vacuum-Steam-Compaction	San-I-Pak (Tracy, CA)	26,000-500,000
Steam-Mixing-Fragmenting/ Drying/Shredding	Tempico (Madisonville, LA)	382,000 +
Shredding/Steam-Mixing/Drying, Chemical	Sterile Technologies Inc. (West Chester, PA)	367,000-427,000
Shredding-Steam-Mixing/Drying	Antaeus Group (Hunt Valley, MD)	200,000
Shredding-Steam-Mixing/Drying	Ecolotec (Union Grove, AL)	325,000
Steam-Mixing-Fragmenting/Drying	Hydroclave Systems Corp. (Kingston, Ontario, Can.)	200,000-500,000
Pre-Shredding/Steam-Mixing	Aegis Bio-Systems (Edmond, OK)	N/a
Shredding/Steam-Mixing-Compactino	LogMed (Erdwich ZerkleinerungsSysteme GmbH	N/a
Microwave Treatment	Sanitec (West Caldwell, NJ)	500,000-600,000
Microwave Treatment	Sintion/CMB (Austria)	45,000
Electro-Thermal Deactivation	Stericycle (Lake Forest, IL)	N/a
Dry Heat Treatment	KC MediWaste (Dallas, TX)	385,000
Dry Heat Treatment	Demolizer	4,000
MEDIUM-HEAT THERMAL PROCESSES		
Reverse Polymerization	Environmental Waste International (Ajax, Ontario)	N/a
Thermal Depolymerization	Changing World Technologies (West Hempstead, NY)	N/a
HIGH HEAT THERMAL PROCESSES		
Pyrolysis-Oxidation	Oxidation Technologies (Annapolis, MD)	1.6 M – 3.3 M
Plasma Pyrolysis	DayStar/Prometron (Tokyo, Japan)	N/a
Plasma Pyrolysis	Electro-Pyrolysis, Inc. (Wayne, PA)	600,000-1,000,000
Plasma Pyrolysis	HI Disposal Systems (Indianapolis, IN)	3 M
Plasma Pyrolysis	Integrated Environmental Systems (Richland, WA)	N/a
Plasma Pyrolysis	MSE Technology Applications (Butte, MT)	N/a
Plasma Pyrolysis	Plasma Pyrolysis Systems (Stuyvesant Falls, NY)	N/a
Plasma Pyrolysis	Startech Environmental Corp. (Wilton, CT)	N/a
Plasma Pyrolysis	Unitel Technologies (Mt. Prospect, IL)	N/a
Plasma Pyrolysis	Vance IDS/Bio Arc (Largo, FL)	750,000
Plasma Pyrolysis	Vanguard Research Inc. (Lorton, VA)	N/a
Induction-Based Pyrolysis	Vanish Technologies/LFR (Raritan, NJ)	1,100,000
Laser-Based Pyrolysis	Anara Group (Las Vegas, NV)	N/a
Advanced Thermal Oxidation	NCE Corporation (Carrollton, TX)	776,000
CHEMICAL PROCESSES		
Sodium Hypochlorite-Hammermill	Circle Medical Products (Indianapolis, IN)	295,000
Sodium Hypochlorite-Shredding (mobile)	MedWaste Technologies Corp. (Houston, TX)	N/a
Chlorine Dioxide-Shredding/Grinding	Encore/Medical Compliance (El Paso, TX)	N/a
Ozonation	Lynntech (College Station, TX)	N/a
Electrocatalytic Wet Oxidation	MeDETOX/Delphi Research (Albuquerque, NM)	N/a
"Stericid"-Shredding-Mixing	MCM Environmental Technologies (Gilboa, Israel)	N/a
Dry Inorganic Chemical-Shredding	Positive Impact Waste Solutions (Pearland, TX)	N/a
Dry Inorganic Chemical-Shredding	Premier Medical Technology (Houston, TX)	N/a
Peracetic Acid-Grinding	Ecocycle 10/STERIS Corp. (Mentor, OH)	20,000
Alkaline Hydrolysis	WR^2 (Indianapolis, IN)	365,000 -428,000 for 600-1000 lbs/hr units
IRRADIATION PROCESSES		
Electron Beam	BioSterile Technology (Fort Wayne, IN)	350,000
Electron Beam-Shredding	U. Miami E-Beam (Coral Gables, FL)	1.2 M
BIOLOGICAL PROCESSES		
Enzyme-Based Treatment/Extrusion	Bio Conversion Technologies, Inc. (Norcross, GA)	N/a

N/a = not available. Note: Facilities should check with vendors to get the latest and most accurate prices.

in the second phase, acceptable bidders are then asked to submit price bids that are subsequently evaluated. Depending on the organization's policies, bidding by a sole source may be allowed. Another approach is for the facility to issue a request for proposals (RFPs) which allows more flexibility than a sealed-bid process. Proposals generally involve negotiations with the selected firm prior to the final award of the contract.

Having made a choice, the facility then purchases the equipment and, with advice from the manufacturer, the facility provides engineering and project management, builds or renovates the site where the equipment will be installed, putting in place the required utility service, heating/ventilation/air conditioning (HVAC), auxiliary devices, etc. Alternatively, many technology vendors now offer a "turnkey" arrangement in which the contractor completes most or all the work necessary—project management, engineering design, construction, installation, supply requisitions, start-up, testing, etc.—so that the health care facility receives the entire package ready to operate.

Different financing options are also possible. A health care facility might pay for the technology and its installation through its own revenues allocated within its capital budget. Other facilities may raise funds through loans from banks or other financial institutions. As many health care facilities have limited budgets for major capital investments and are under pressure to cut costs, alternate financing arrangements are offered by some technology vendors or financial institutions. The following is a general description of several financing arrangements that allow health care facilities to acquire a technology without having to pay high capital costs. Many variations of these types of agreements exist.

Lease-purchase agreements allow the health care facility to select a technology and negotiate a purchase price and performance specifications. The lessor then purchases or provides the technology and allows the facility to use the technology for a specific period of time defined in the lease agreement. During the lease term, the facility makes pre-determined periodic payments including taxes and insurance. When the lease term ends, the facility purchases the technology for a pre-determined amount that is at or below its fair market value. Lease-purchase payments include both principal and interest, which may be slightly higher than those for loans, but leases require no down payment.

Another type of financing is a build-operate-transfer (BOT) arrangement. Under provisions of a BOT contract, the technology manufacturer (or a private financing entity) will use its own funds to install the technology at the host facility's site. In return, the manufacturer or private entity is allowed to operate the technology commercially for a set number of years. During that time, the host facility pays the operator a fixed sum (usually a discounted price) per pound of medical waste treated. The BOT contract may allow the manufacturer or private entity to bring in medical waste from other health care facilities and to use the equipment to treat the waste at the host facility. (Some states have specific requirements for sites that function as regional treatment centers by treating waste not generated by that facility. Federal and state laws also apply to the transport of medical waste.) After the allotted number of years, the technology and its operation are then transferred to the host facility.

A variation of this is a build-transfer-operate (BTO) agreement wherein the technology and infrastructure become the property of the facility immediately upon completion, but the manufacturer or private entity is granted the right to operate the technology for a certain period. Other variations include build-rent-operate-transfer (BROT) or build-lease-operate-transfer (BLOT) arrangements in which the private entity rents the physical assets on which the equipment is located for the duration of the agreement. There is also a build-own-operate (BOO) scheme, whereby the technology manufacturer or private financing entity retains ownership of the treatment facility and is not under obligation to transfer it to the host facility in the future.

It may also be possible for a group of hospitals to form a consortium and agree to share the capital and operating costs of a new non-incineration technology. Strategic alliances could also be created between hospitals, nursing homes, clinics, medical offices, veterinary hospitals, and other facilities that generate regulated medical waste within a geographical area. Hospitals that are part of a large hospital chain may be able to negotiate with a vendor to get a reduced price for multiple units.

Performance contracting, an arrangement to provide incentives for achieving specific quantifiable outcomes and disincentives for non-performance, may help cut costs and improve performance and quality of work. As one example of a performance contract, the annual cost savings due to a new technology could be used to cover the cost of the technology (assuming the technology is expected to lower costs significantly). A similar approach is a "shared savings" arrangement between a hospital that provides the site and the workers, the manufacturer that provides the technology, utilities that provide utility service, and other entities that contribute in cash or in kind to the project. The annual savings are computed based on a baseline cost of medical waste treatment and disposal before the technology was installed.

Facilities may also be able to negotiate a highly discounted price for a new or emerging technology in return for allowing the vendor to use the hospital as a demonstration site for their technology. There are obvious risks in being the first facility to try a new technology but significant savings offered by the vendor may outweigh the risks. Health care organizations should explore these and other options for acquiring a non-incineration technology.

NOTES

1. "Approach Used to Estimate the Capital and Annual Costs for MWI Wet Scrubbers"; "Revised Costs for Dry Injection/Fabric Filter Controls for MWI"; "Revised Costs for Secondary Chamber Retrofits for MWI"; "Annual Costs for the Operator Training and Qualification Requirements for MWI Operators"; "Cost Impacts of the Regulatory Options for New and Existing Medical Waste Incinerator (MWI)"; and "Testing and Monitoring Options and Costs for MWI – Methodology and Assumptions"; documents in Air Docket No. A-91-61, Air and Radiation Docket and Information Center, U.S. Environmental Protection Agency, Washington, DC.
2. MATES is a product of the Healthcare Initiative, EPRI, 3412 Hillview Avenue, Palo Alto, CA 94303.

Chapter 12

References and Recommended Readings

C.L. Bisson, G. McRae, and H.G. Shaner. *An Ounce of Prevention: Waste Reduction Strategies for Health Care Facilities*. (Chicago, IL: American Society for Healthcare Environmental Services (American Hospital Association), 1993).

C. R. Brunner, *Medical Waste Disposal*. (Reston, VA: Incinerator Consultants Incorporated, 1996).

E. Cole. "Chemical and Biological Exposures and Safety Hazards in Medical Waste Treatment Facilities: An Assessment of Alternative Technologies." Vol. 98/2, No. 9 (Cedex, France: International Healthcare Waste Network (IhcWaN), August 31, 1998).

F.L. Cross, H.E. Hesketh, and P.K. Rykowski. *Infectious Waste Management*. (Lancaster, PA: Technomic Publishing Company, Inc., 1990).

J. Emmanuel. "Alternative Technologies for Medical Waste Treatment," workshop presented at the People's Dioxin Action Summit, University of California at Berkeley, August 13, 2000.

J. Emmanuel. "Medical Waste Management," in Chapter 9 of *Facilities Engineering and Management Handbook*. (New York, NY: McGraw-Hill Book Company, December 2000).

J. Emmanuel. *New and Emerging Technologies for Medical Waste Treatment*. EPRI Healthcare Initiative Report CR-107836-R1. (Palo Alto, CA: EPRI, 1999).

J. Emmanuel and M. Jones. "A Review of Alternative Treatment Technologies for Medical Waste," poster presentation at the 33rd Annual Conference & Technical Exhibit, American Society of Healthcare Engineering, Orlando, Florida, June 24-25, 1996.

Health Care Without Harm. "Medical Waste Treatment Technologies: Evaluating Non-Incineration Alternatives." (Minneapolis, MN: HCWH c/o Institute for Agriculture and Trade Policy, May 2000).

M. Kela, S. Nazareth, and R. Agarwal. "Managing Hospital Waste: A Guide for Health Care Facilities." (New Delhi, India: Srishti, September 1998).

M.G. Malloy. "Medical Waste – Part II: Alternative Medical Waste Technologies – Poised for Takeoff?" *Waste Age*, Vol. 28, No. 8. (Washington, DC: Environmental Industry Association, August 1997).

G. McRae and H.G. Shaner. *Guidebook for Hospital Waste Reduction Planning and Program Implementation.* (Chicago, IL: American Society of Healthcare Environmental Services (American Hospital Association), 1996).

D. NaQuin. "Medical Waste: Still Healthy After All These Years." *Waste Age*, Vol. 29, No. 7. (Washington, DC: Environmental Industry Association, July 1998).

K. Owen, K. Leese, L. Hodson, R. Uhorchak, D. Greenwood, D. VanOsdell, and E. Cole. "Control of Aerosol (Biological and Nonbiological) and Chemical Exposures and Safety Hazards in Medical Waste Treatment Facilities." (Cincinnati, OH: National Institute of Occupational Safety and Health, November 1997).

P.A. Reinhardt and J.G. Gordon. *Infectious and Medical Waste Management*. (Chelsea, MI: Lewis Publishers, Inc., 1991).

W.A. Rutala. "Management of Infectious Waste by U.S. Hospitals." *JAMA*, Vol. 262 (12). (September 22, 1989).

W.A. Rutala and C.G. Mayhall. "Medical Waste." *Infection Control and Hospital Epidemiology*, Vol. 13 (1), January 1992, 38-48.

STAATT I. "Technical Assistance Manual: State Regulatory Oversight of Medical Waste Treatment Technologies." State and Territorial Association on Alternative Treatment Technologies, April 1994; www.epa.gov/epaoswer/other/medical/index.htm

STAATT II. "Technical Assistance Manual: State Regulatory Oversight of Medical Waste Treatment Technologies: A Report of the State and Territorial Association on Alternative Treatment Technologies." EPRI Report TR-112222. (Palo Alto, CA: EPRI, 1998).

W.L. Turnberg. *Biohazardous Waste: Risk Assessment, Policy and Management.* (New York, NY: John Wiley & Sons, Inc. 1996).

Underwriters Laboratories. "Standard for Alternative Treatment Technologies for the Disposal of Medical Waste." Draft ANSI/UL Standard, UL-2334 (Research Triangle Park, NC: Underwriters Laboratories, 2000); www.ul.com/eph/medwaste.htm

U.S. Environmental Protection Agency. Documents in Air Docket No. A-91-61. (Washington, DC: Air and Radiation Docket and Information Center, 1997).

U.S. Environmental Protection Agency. "EPA Guide for Infectious Waste Management." EPA/530-SW-86-04. (Springfield, VA: National Technical Information Service, May 1986).

U.S. Environmental Protection Agency. "Guides to Pollution Prevention: Selected Hospital Waste Streams." EPA/625/7-90/009. (June 1990).

K.D. Wagner, C.D. Rounds, and R.A. Spurgin. Editors. *Environmental Management in Healthcare Facilities*. (Philadelphia, PA: W.B. Saunders Company, 1998).

Vendor literature (see footnotes).

Appendix 1

List of Alternative Technologies and Contact Information

Note: Health Care Without Harm does not endorse any particular technology or company. This is not intended to be an exhaustive list, and neither HCWH nor the consultant/author is responsible for the accuracy of the contact 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

Anara Group Limited
Wells Fargo Financial Center
3770 Howard Hughes Parkway 195
Las Vegas, NV 89109
Ph. 702-220-8405
Fax 800-863-8541
www.anara.com

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

Balboa Pacific Corporation
11240 Bloomfield Avenue
Santa Fe Springs, CA 90670
Ph. 562-929-1633
(see also The Hallwood Group)

Bio Arc
11440 66th Street N
Largo, FL 33773
Ph. 727-548-0640
Fax 727-549-8097

Biomedical Disposal, Inc.
3690 Holcomb Bridge Road
Norcross, GA 30092
Ph. 770-300-9595 or 888-393-9595
Fax 770-300-9599
www.biodisposal.com

BioSterile Technology, Inc.
4104 Merchant Road
Fort Wayne, IN 46818
Ph. 888-710-3792 or 219-489-2961
Fax 219-489-3654
www.biosterile.com
info@biosterile.com

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

CerOx Corporation
760 San Aleso Avenue
Sunnyvale, CA 94086
Ph. 408-744-9180
www.cerox.com

Changing World Technologies, Inc.
460 Hempstead Avenue
West Hempstead, NY 11552
Ph. 516-486-0100
Fax 516-486-0460
cwt@changingworldtech.com

Circle Medical Products, Inc.
3950 Culligan Avenue #D
Indianapolis, IN 46218
Ph. 317-541-8080

Daystar / Prometron Technics Corporation
Nibancho-on Building 47 11-6
Nibancho, Chiyoda-ku
Tokyo 102, Japan
Ph. 81-3-5275-2411
Fax 81-3-5275-2415

or M. Funai of Masuda, Funai, Eifert & Mitchell
One East Wacker Drive
Chicago, IL 60601

Delphi Research, Inc.
701 Haines Avenue NW
Albuquerque, NM 87102
Ph. 505-292-9315

Duratek
10100 Old Columbia Road
Columbia, MD 21046
www.gtsduratek.com

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

Electro-Pyrolysis, Inc.
996 Old Eagle School Road
Wayne, PA 19087
Ph. 610-687-9070,
Fax 610-964-8570

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

Environmental Waste International
283 Station Street
Ajax, Ontario L1S 1S3 Canada
Ph. 905-686-8689
Fax 905-428-8730
www.wemc.com
sales@ewmc.com

The Hallwood Group, Inc.
1306 Countryside Place
Smyrna, GA 30080
Ph. 770-436-5027
Fax 770-438-0002
(see also Balboa Pacific Corporation)

HI Disposal Systems
P.O. Box 1724
Indianapolis, IN 46206-1724
Ph. 317-693-1265 or 800-995-1265
Fax 317-262-1265
www.hawkinsindustries.com
info@hicompanies.com

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

Integrated Environmental Technologies LLC
1535 Butler Loop
Richland, WA 99352
Ph. 509-946-1901
Fax 509-946-1819
www.inentec.com
inentec1@inentec.com

KC MediWaste
4219 University Boulevard
Dallas, TX 75205
Ph. 214-528-8900
Fax 214-528-0467

LogMed / Erdwich ZerkleinerungsSysteme GmbH
(Kolpingstrassa 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)

Lynntech, Inc.
7610 Eastmark Drive, Suite 105
College Station, TX 77840
Ph. 409-693-0017
Fax 409-764-7479

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

Matrix Technology Pty. Ltd.
P.O. Box 1213
Cairns, Queensland, Australia 4870
Ph. 617-40512955
Fax 617-40518709
www.iig.com.au/matrix

MCM Environmental Technologies
Moledet, M.P.
Gilboa 19130
Israel
Ph. 972-6-653-1104

Medical Compliance Services
5307 El Paso Drive
El Paso, TX 79905
Ph. 800-274-4627

Medical Disposal Devices
P.O. Box 523
11 Halls Road
Old Lyme, CT 06371
Ph. 888-881-3477
Fax 860-434-3690
www.meddisposal.com
mdd@meddisposal.com

Medical Innovations
P.O. Box 148
Wayland, MA 01778
Ph. 508-358-8099
Fax 508-358-2131
medicalinn@mediaone.net

MedPro, Inc.
817 Winchester Road
Lexington, KY 40505
Ph. 606-225-5375
Fax 606-225-5347
www.needlyzer.com
eadams@needlyzer.com

MedWaste Technologies Corporation
6830 N. Eldridge Parkway
Building 110
Houston, TX 77041
Ph. 713-849-5480
Fax 713-849-9774
www.medwastetech.com

MSE Technology Applications, Inc.
200 Technology Way
P.O. Box 4078
Butte, MT
Ph. 406-494-7100
Fax 406-494-7230
www.mse-ta.com
mseta@buttenet.com

NCE Concepts
2150 Chennault
Carrollton, TX 75006
Ph. 214-991-4090
Fax 214-991-9334

OBF Technologies
2719 Curtiss Street
Downers Grove, IL 60515
Ph. 800-848-5663
Fax 630-515-9526
www.enviro-safe.com
obfind@aol.com

Oxidation Technologies, Inc.
613 Third Street
Annapolis, MD 21403
Ph. 410-990-9430
Fax 410-990-9431
www.oxid-tech.com
barrj@oxid-tech.com

Plasma Pyrolysis Systems, Inc.
Box 158
Stuyvesant Falls, NY 12174
Ph. 518-828-4684
Fax 518-822-0132

Positive Impact Waste Solutions, Inc.
4110 Rice Dryer Boulevard
Pearland, TX 77581
Ph. 281-412-9991
Fax 281-997-1007

Premier Medical Technology, Inc.
525 North Sam Houston
Parkway East
Houston, TX 77060
Ph. 281-448-2399

San-I-Pak
23535 South Bird Road
Tracy, CA 95376

or P.O. Box 1183
Tracy, CA 95378-1183
Ph. 209-836-2310
Fax 209-836-2336
www.sanipak.com
sanipak@sanipak.com

Sanitec International Holdings
26 Fairfield Place
West Caldwell, NJ 07006
Ph. 973-227-8855
Fax 973-227-9048
www.sanitec-inc.com
sales@sanitec.net

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

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

SPS Medical Equipment Corporation
450 West First Avenue
Roselle, NJ 07203
Ph. 800-978-8006

Startech Environmental Corporation
79 Old Ridgefield Road
Wilton, CT 06897
Ph. 203-762-2499
Fax 203-761-0839
www.startech.net
startech@netaxis.com

Stericycle, Inc.
28161 N. Keith Drive
Lake Forest, IL 60045
Ph. 847-367-5910

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

Steris Corporation
5960 Heisley Road
Mentor, OH 44060
Ph. 800-548-4873 or 440-354-2600
Fax 440-639-4450
www.steris.com

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

Svedala Industries, Inc.
350 Railroad Street
Danville, PA 17821-2046
Ph. 570-275-3050
Fax 570-275-6789

Tempico, Inc.
P.O. Box 428
Madisonville, LA 70447-0428

or 251 Highway 21 North
Madisonville, FA 70447
Ph. 800-728-9006 or 504-845-0800
Fax 504-845-4411
www.tempico.com

Thermal Waste Technologies, Inc.
19 Stony Hill Road
Bethel, CT 06801
Ph. 888-336-6549 or 203-778-2210
Fax 203-778-3114

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

Unitel Technologies
411 Business Center Drive
Suite 111
Mt. Prospect, IL 60056
Ph. 847-297-2265
Fax 847-297-1365

University of Miami
(Prof. Charles Kurucz or Dean Thomas Waite)
Laboratories for Pollution Control Technologies
P.O. Box 248294
Coral Gables, FL 33124
Ph. 305-284-2423 or 284-2908
Fax 305-284-2321 or 305-284-2885

Vanish Technologies
c/o Joanne Jaeger
Levine Fricke Recon
5 Johnson Drive
Raritan, NJ 08869
Ph. 908-526-1000 ext. 450
Fax 908-526-0923
Joanne.jaeger@lfr.com

Vanguard Research, Inc.
8384-C Terminal Road
Lorton, VA 22079
Ph. 703-339-6222
Fax 703-339-6835
www.vriffx.com
info@vripeps.com

Waste Reduction by Waste Reduction, Inc.
5711 W. Minnesota Street
Indianapolis, IN 46241
Ph. 317-484-4200
Fax 317-484-4201
www.wr2.net
wr2@wr2.net

Appendix 2

State Regulations for Pathological Waste

Table prepared by Jessica Nelson, Institute for Agriculture & Trade Policy, 2001

STATE	PATHOLOGICAL WASTE REGULATION (Y/N)	TYPE OF WASTE	TREATMENT REQUIRED	COMMENTS
Alabama[1]	Yes	Recognizable human tissue, organs, body parts	Incineration, steam sterilization and rendered unrecognizable	
Alaska[2]	No			
Arizona[3]	Yes	Recognizable human tissue, organs, body parts	Rendered unrecognizable through grinding, shredding or other process	
Arkansas[4]	Yes	Pathological waste	Rendered unrecognizable	
California[5]	Yes	Recognizable human anatomical parts	Incineration, consultation with Department of Health Services	Recent law change allowed for treatment other than incineration; consult Department of Health Services for specifics
Colorado[6]	Yes	Recognizable human anatomical remains	Incineration, interment	
Connecticut[7]	Yes	Pathological waste	Incineration, interment	
Delaware[8]	Yes	Pathological waste	Incineration, interment	
DC[9]	No			
Florida[10]	No			
Georgia[11]	Yes	Recognizable human anatomical remains	Cannot be landfilled	
Hawaii[12]	Yes	Pathological waste	Incineration, sterilization, disinfection	
		Recognizable human body parts	Incineration, disposal in accordance with state laws governing the disposal of human remains	
Idaho[13]	No			
Illinois[14]	No			
Indiana[15]	No			
Iowa[16]	No			

STATE	PATHOLOGICAL WASTE REGULATION (Y/N)	TYPE OF WASTE	TREATMENT REQUIRED	COMMENTS
Kansas[17]	No			
Kentucky[18]	Yes	Pathological waste, which includes all tissue specimens from surgical or necropsy procedure	Incineration	
Louisiana[19]	Yes	Human bodies, gross anatomical parts, fetal remains	Burial, cremation, other means specifically authorized by law	
Maine[20]	Yes	Pathological waste	Incineration, interment	
Maryland[21]	No			
Massachusetts[22]	Yes	Pathological waste	Incineration, interment	
		Liquid pathological waste	Disposal into municipal sewerage system or septic system; incineration; gas, chemical or steam sterilization and landfilling	
		Discarded teeth and tissue	Rendered noninfectious by steam sterilization, incineration, thermal inactivation, chemical disinfection and landfilled	
Michigan[23]	Yes	Pathological waste	Incineration, cremation, grinding and flushing in sanitary sewer, burial in cemetery, grinding until unrecognizable and landfilling, alternative approved technologies	
Minnesota[24]	No	Recognizable body parts (other than teeth) and fetal remains		
Mississippi[25]	No			Department of Health standards for health care facilities licensed by State require that recognizable human anatomical remains be incinerated or interred unless burial is authorized
Missouri[26]	No			
Montana[27]	Yes	Limbs and recognizable organs, excluding teeth and gum tissue	Incineration, interment	
Nebraska[28]	No			
Nevada[29]	No			

STATE	PATHOLOGICAL WASTE REGULATION (Y/N)	TYPE OF WASTE	TREATMENT REQUIRED	COMMENTS
New Hampshire[30]	Yes	Limbs and recognizable organs, excluding teeth and gum tissue	Incineration, burial	
New Jersey[31]	No			
New Mexico[32]	Yes	Recognizable human anatomical remains	Incineration, interment	
New York[33]	Yes	Recognizable body parts	Incineration, interment	
North Carolina[34]	Yes	Pathological waste	Incineration	
North Dakota[35]	No			
Ohio[36]	Yes	Pathological waste	Incineration, autoclaving (if facility performs one-time validation test)	
Oklahoma[37]	No			
Oregon[38]	Yes	Pathological waste	Incineration	
Pennsylvania[39]	Yes	Human anatomical remains	May not be landfilled unless incinerated	
Rhode Island[40]	Yes	Pathological waste (not including body fluids)	Incineration	
South Carolina[41]	Yes	Recognizable human anatomical remains	Interment, donation for medical research	
South Dakota[42]	No			
Tennessee[43]	No			
Texas[44]	Yes	Body parts	Incineration, interment, steam disinfection and interment, moist heat or chlorine disinfection (provided that grinding/shredding renders unrecognizable) and landfill, approved process that renders unrecognizable	
		Tissues, fetuses, organs	Incineration, grinding and discharging to sanitary sewer, interment, steam disinfection and interment, moist heat or chlorine disinfection and landfill, approved process that renders unrecognizable	
		Anatomical remains	Incineration, interment, steam disinfection and interment	
Utah[45]	No			

STATE	PATHOLOGICAL WASTE REGULATION (Y/N)	TYPE OF WASTE	TREATMENT REQUIRED	COMMENTS
Vermont[46]	No			Proposed procedures for the definition, handling and treatment of medical waste would require the incineration of pathological waste; the procedure is expected to be signed in May, 2001
Virginia[47]	No			
Washington[48]	No			
West Virginia[49]	Yes	Anatomical parts	Incineration, burial	
Wisconsin[50]	Yes	Human tissue	Incineration, rendered noninfectious and unrecognizable	
Wyoming[51]	No			

1. Personal communication; Alabama Rules and Regulations 335-13-7.08(2)(b)(2)
2. Personal communication; Alaska Administrative Code 18AAC60.030
3. Personal communication; Arizona Administrative Code R18-13-1405 D.1 and E.2
4. Personal communication
5. Personal communication; Medical Waste Management Act (CA Health and Safety Code) Section 118220
6. Personal communication; Colorado Solid Waste Regulations 1007-2 Section 13.4.4
7. Personal communication; Connecticut General Statutes 22a-209(c)(b)(2)
8. Personal communication; Delaware Solid Waste Regulations Section 11 Part 1,K,2
9. Personal communication
10. Personal communication; Florida Administrative Code 64E-16.007
11. Personal communication; Georgia Environmental Rules 391-3-4-.15.6(c)
12. Personal communication; Hawaii Administrative Rules 11-104-5(c)4 and 11-104-9(d)
13. Personal communication
14. Personal communication; 35 Illinois Administrative Code 1422
15. Personal communication; Indiana Administrative Code Title 410, rule 3
16. Personal communication
17. Personal communication, Kansas Administrative Regulations 28-29-27
18. Personal communication, 902 Kentucky Administrative Regulations 20:016 Section 3(10)(h)(3)(b)
19. Personal communication; Louisiana Sanitary Code 27:025-7
20. Personal communication, Code of Maine Rules 06-096 Chapter 900 Section 10A
21. Personal communication
22. 105 Code of Massachusetts Regulations 480.200 E
23. Personal communication; Michigan Medical Waste Regulatory Act of l990 Section 13811(C)
24. Personal communication; Minnesota Statutes 116.76
25. Personal communication; "Adopted Standards for the Regulation of Medical Waste" in Health Care Facilities Licensed by the Mississippi State Department of Health, Medical Waste Management Plan Part II(D)
26. Personal communication; Missouri Rules 10 CSR 80-7
27. Personal communication; Montana Code Annotated 75-10-1005(4)(c)
28. Personal communication; Nebraska Rules Title 132 Chapter 13
29. Nevada Administrative Code 444.646
30. Personal communication; New Hampshire Code of Administrative Rules Env-Wm 2604.08
31. Personal communication; New Jersey Administrative Code 7:26-3A
32. 20 New Mexico Administrative Code 9.1-706(D)(5)
33. New York Codes, Rules and Regulations Title 6 360-10.5(b)
34. Personal communication; North Carolina Rules 1203(a)(3)
35. Personal communication; North Dakota Solid Waste Management Rules 33-20-12
36. Personal communication; Ohio Administrative Code 3745-27-32(D)(1)(f)
37. Personal communication; Oklahoma Department of Environmental Quality Rules 252:520-19
38. Personal communication; Oregon Revised Statutes 459.395(1)
39. Personal communication; Pennsylvania Code 273.511(b)
40. Personal communication; Rhode Island Regulations 15.07(C)(2)
41. Personal communication; South Carolina Regulations R.61-105.T(5)(b)
42. Personal communication; South Dakota Administrative Rules 74:35
43. Personal communication
44. 25 Texas Administrative Code Rule 1.136(4)
45. Personal communication; Utah Environmental Rules R315-316
46. Personal communication; Vermont Solid Waste Management Rules 6-802(b)
47. Personal communication; Virginia Waste Regulations Chapter 120; "Draft Procedure Addressing Medical Waste Definitions and the Handling and Treatment of Medical Waste," June 30, 2000
48. Personal communication; Revised Code of Washington 70.95(k)
49. Personal communication; West Virginia Code of State Rules 64CSR56
50. Personal communication; Wisconsin Administrative Codes 526.11(2)(a)
51. Personal communication

Index

I

K

L

M

N

O

P

Q

R

S

T

U

V

W

Health Care Without Harm
1755 S Street, N.W.
Suite 6B
Washington, DC 20009
Phone: 202.234.0091
www.noharm.org



Printed with soy-based inks
on Rolland Evolution,
a 100% processed chlorine-free paper.