



# Compendium of Technologies for Treatment/Destruction of Healthcare Waste

United Nations Environment Programme

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgement of the source is made. UNEP would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme.

### **Acknowledgement**

This document was written by Dr. JORGE EMMANUEL, Consultant, under the overall guidance and supervision of Surya Prakash Chandak, Senior Programme Officer, International Environmental Technology Centre, Division of Technology, Industry & Economics, United Nations Environment Programme. It was peer reviewed and tested for applicability in the field during an International Experts' Workshop that was participated by the following:

1. Dr. Edith CLARKE, Program Manager, Occupational and Environmental Health Unit, Ghana Health Service, Ministry of Health PMB, Government of Ghana
2. Mr. Mohammad-Ali HAMANDI, Assistant CEO, Makassed Hospital, Syndicate of Hospitals in Lebanon
3. Mr. Yoshihiko HORI, Senior Executive Corporate Officer, Plantec Inc., Japan
4. Prof. Babacar NDOYE, Coordonnateur du PRONALIN, Ministry of Health and Social Action (Ministère de la Santé et l'Action Sociale), Senegal
5. Dr. Arturo M. PESIGAN, Technical Officer, Team Leader, Urban Health Emergency Management, WHO Centre for Health Development (WHO Kobe Centre), Japan
6. Dr. Megha RATHI, Consultant, UNDP GEF Project HCWM, India
7. Ms. Ruth STRINGER, International Science and Policy Coordinator, Healthcare without Harm, United Kingdom
8. Ms. Susan WILBURN, Technical Officer, Department of Health and Environment, World Health Organization, Switzerland
9. Mr. Makoto IWAKAWA, Waste Management and Recycling Department, Ministry of Environment, Government of Japan
10. Dr. Osamu YAMAMOTO, Director, Nutrition College, Osaka City Institute of Public Health and Environmental Sciences, Japan

### **Disclaimer**

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

# **Compendium of Technologies for Treatment/Destruction of Healthcare Waste**

Compiled by



United Nations Environment Programme  
Division of Technology, Industry and Economics  
International Environmental Technology Centre  
Osaka, Japan

# Table of Contents

EXECUTIVE SUMMARY .....	1
I. INTRODUCTION.....	3
1 Introduction to Healthcare Waste .....	3
1.1 Definitions.....	3
1.2 Sources of Healthcare Waste.....	3
2 Health and Environmental Impacts of Healthcare Waste .....	5
3 Purpose of the Compendium .....	9
II. BASIC DATA ON HEALTHCARE WASTE .....	10
4 Constituents and Other Basic Properties of Healthcare Waste .....	10
4.1 Material Constituents of Healthcare Waste .....	10
4.2 Moisture Content of Healthcare Waste.....	12
4.3 Percent Incombustibles in Healthcare Waste.....	13
4.4 Heating Value of Healthcare Waste.....	13
4.5 Chemical Composition of Healthcare Waste .....	14
4.6 Bulk Density of Healthcare Waste .....	15
5 Classifications and Composition of Healthcare Waste.....	16
6 Healthcare Waste Generation Rates .....	20
7 Summary of Estimation Factors for Healthcare Waste.....	26
8 Overview of Healthcare Waste Management.....	28
9 Process of Technology Selection .....	33
10 Waste Generation Data Gathering .....	38
III. GENERIC TECHNOLOGIES.....	40
11 Treatment Technologies for Healthcare Waste.....	40
11.1 Overview .....	40
11.2 Types of Treatment Technologies .....	40
11.2.1 Thermal processes .....	40
11.2.2 Chemical processes.....	41
11.2.3 Irradiative Processes.....	42
11.2.4 Biological processes.....	42
11.2.5 Mechanical processes.....	42
11.3 Detailed Description of Generic Treatment Technologies.....	45
11.3.1 Autoclaves .....	45
11.3.2 Hybrid autoclave systems.....	50
11.3.3 Continuous steam treatment systems.....	56
11.3.4 Batch microwave technologies.....	58
11.3.5 Continuous microwave technologies.....	61
11.3.6 Frictional heat treatment systems .....	64
11.3.7 Dry heat treatment systems.....	66
11.3.8 Incinerators and related technologies.....	68
11.3.9 Alkaline hydrolysis technologies.....	78
11.3.10 Chemical treatment systems.....	81
11.4 Others .....	85
11.5 Specific Considerations for Developing Countries .....	86
11.5.1 Environmental and occupational safety aspects .....	86
11.5.2 Social aspects and job potential.....	88
11.5.3 Investment and operating costs .....	90
11.5.4 Institutional and regulatory requirements .....	95
11.5.5 Summary of pros and cons for developing countries .....	97
11.6 Examples of Specific Applications.....	98
11.6.1 Small autoclave-shredder for a district hospital.....	98
11.6.2 Autoclave-shredder at a central treatment facility.....	99
11.6.3 Large autoclave at a central treatment facility.....	99
11.6.4 Hybrid autoclave at an urban hospital and other hospitals .....	100

11.6.5	Hybrid vertical autoclave at a large urban hospital.....	100
11.6.6	Continuous steam treatment at a tertiary urban hospital.....	101
11.6.7	Rotating autoclave at a central treatment plant and a batch microwave at a hospital.....	101
11.6.8	Continuous microwave unit at a central treatment plant.....	102
11.6.9	Frictional heat treatment unit at a hospital.....	103
11.6.10	High-tech incinerator at a central treatment plant.....	103
11.6.11	Alkaline hydrolysis technology at a veterinary lab.....	104
IV.	SPECIFIC TECHNOLOGIES.....	105
12	Specific Technologies for Healthcare Waste Treatment.....	105
12.1	Autoclaves.....	105
12.1.1	AWS Clinical Waste.....	105
12.1.2	Bondtech.....	106
12.1.3	CISA.....	108
12.1.4	GEF Technology.....	110
12.1.5	GK Moss.....	111
12.1.6	Incol.....	113
12.1.7	MachinFabrik.....	115
12.1.8	Mark-Costello.....	116
12.1.9	Matachana / Webeco.....	118
12.1.10	Medclean Technologies.....	120
12.1.11	OnSite Sterilization/Variclave.....	121
12.1.12	Safewaste Technologies.....	123
12.1.13	San-I-Pak.....	124
12.1.14	Steridium.....	126
12.1.15	Tuttnauer.....	128
12.2	Hybrid Autoclave Systems.....	130
12.2.1	Celitron.....	130
12.2.2	Ecodas.....	131
12.2.3	Ecolotec.....	133
12.2.4	Hydroclave.....	134
12.2.5	MedFreshe/Narula Group.....	136
12.2.6	Medivac Metamizer.....	138
12.2.7	Metan.....	139
12.2.8	RedBag Solutions.....	141
12.2.9	Sazgar.....	142
12.2.10	T.E.M. Steriflash and Steri2flash.....	144
12.2.11	Tempico Rotoclave.....	145
12.3	Continuous Steam treatment systems.....	147
12.3.1	BioSafe Engineering.....	147
12.3.2	Erdwich.....	149
12.3.3	LogMed.....	151
12.3.4	Miclo.....	152
12.4	Batch Microwave Technologies.....	154
12.4.1	Meteka.....	154
12.4.2	Sintion.....	155
12.4.3	Sterifant-Sterival.....	157
12.5	Continuous Microwave Technologies.....	159
12.5.1	AMB Ecosteryl.....	159
12.5.2	Micro-Waste.....	160
12.5.3	Sanitec.....	162
12.6	Frictional Heat Treatment Systems.....	163
12.6.1	Newster.....	163
12.6.2	OMPeco.....	165
12.7	Dry Heat Treatment Systems.....	167
12.7.1	Demolizer.....	167
12.7.2	Sterigerms.....	169

12.8	Incinerators and Related Technologies .....	170
12.8.1	<i>Advanced Combustion Systems</i> .....	170
12.8.2	<i>ATI Incinerateurs Muller</i> .....	172
12.8.3	<i>BIC systems</i> .....	174
12.8.4	<i>Consutech</i> .....	175
12.8.5	<i>Hafner</i> .....	177
12.8.6	<i>Incinco</i> .....	178
12.8.7	<i>Kureba</i> .....	180
12.8.8	<i>Pennram</i> .....	181
12.8.9	<i>Plantec</i> .....	183
12.8.10	<i>Techtrol/Incol</i> .....	184
12.9	Alkaline Hydrolysis Technologies .....	187
12.9.1	<i>BioResponse</i> .....	187
12.9.2	<i>BioSafe Engineering</i> .....	189
12.9.3	<i>Peerless Waste Solutions</i> .....	191
12.9.4	<i>PRI</i> .....	192
12.10	Chemical Treatment Systems .....	194
12.10.1	<i>PIWS</i> .....	194
12.10.2	<i>Sterimed</i> .....	195
12.10.3	<i>Trinova</i> .....	197
12.11	Other Technologies .....	199
12.11.1	<i>Crusader Engineering</i> .....	199
12.11.2	<i>Grupo Athisa</i> .....	199
12.11.3	<i>Lizhong Medical Waste retort</i> .....	199
12.11.4	<i>Oncore</i> .....	200
12.11.5	<i>ReGen Vanish</i> .....	200
12.11.6	<i>SES Sharpsblaster</i> .....	200
12.11.7	<i>Tianjin GreenTech</i> .....	201
12.11.8	<i>Zealway (Xiamen) Medical Waste Sterilizer</i> .....	201
V.	TECHNOLOGY ASSESSMENT METHODOLOGY .....	202
13	Sustainability Assessment of Technologies .....	202
13.1	Overview .....	202
13.2	Steps of the Overall SAT methodology .....	202
13.3	Operational Level Assessment.....	204
13.3.1	<i>Tier 1 screening</i> .....	204
13.3.2	<i>Tier 2 scoping</i> .....	205
13.3.3	<i>Tier 3 detailed assessment</i> .....	208
13.3.4	<i>Review and justification</i> .....	209
13.4	Recommended Steps Using the SAT methodology .....	209
13.4.1	<b>Step 1.</b> <i>Define the scope of the problem, obtain baseline data, and conduct stakeholder consultations</i> ...209	
13.4.2	<b>Step 2.</b> <i>Conduct a strategic level assessment and determine the desired waste treatment approach</i> .....	211
13.4.3	<b>Step 3.</b> <i>Verify facility-specific data or obtain additional facility-specific data through a waste assessment or comparison with estimation factors</i> .....	211
13.4.4	<b>Step 4.</b> <i>Conduct a Tier 1 screening process to eliminate generic technologies that do not meet the basic criteria</i> .....	212
13.4.5	<b>Step 5.</b> <i>Conduct a Tier 2 scoping process to generate a shorter list of potential technologies</i> .....	213
13.4.6	<b>Step 6.</b> <i>Conduct a Tier 3 detailed assessment to come up with a ranking of the top technologies</i> .....	222
13.4.7	<b>Step 7.</b> <i>Review the results and prepare a written justification for the selection of the top technologies</i> ....	224
13.4.8	<b>Step 8.</b> <i>Award the contract</i> .....	224
13.4.9	<b>Step 9.</b> <i>Implement the installation and commissioning of the technology</i> .....	224
13.4.10	<b>Step 10.</b> <i>Monitor and evaluate the performance of the technology</i> .....	224

## **EXECUTIVE SUMMARY**

Healthcare waste is all the waste generated by healthcare facilities, medical laboratories and biomedical research facilities, as well as waste from minor or scattered sources. The bulk of healthcare waste is produced by hospitals. Improper treatment and disposal of healthcare waste pose serious hazards of disease transmission due to exposures to infectious agents among waste pickers, waste workers, health workers, patients, and the community in general. Open burning and incineration without adequate pollution control expose waste workers and the community to toxic contaminants in air emissions and ash.

This compendium reviews basic data on healthcare waste, including material constituents, moisture content, incombustibles, heating value, chemical composition, and bulk density. The classifications of healthcare waste are described following the World Health Organization's classification system as found in the WHO reference guidelines *Safe management of wastes from health-care activities*. In general, between 75% and 90% of the waste produced by healthcare facilities is non-risk (non-infectious, non-hazardous) general waste, comparable to domestic waste. Only a small portion of healthcare waste is regarded as hazardous and may create health risks. An assessment of waste generation rate data from around the world shows that about 0.5 kg per bed per day is produced in hospitals. The compendium recommends qualitative factors and estimation parameters pertaining to healthcare waste.

Treatment technologies are an integral part of a healthcare waste management system which includes both best available technologies and best environmental practices. Segregation is the key to efficient healthcare waste management. Other elements of healthcare waste management are: waste classification, waste minimization, containerization, color coding, labeling, signage, handling, transport, storage, treatment, and final disposal. Planning and implementation of a healthcare waste management system must address compliance with regulations, defining roles and responsibilities of healthcare staff, specific procedures, and training. The process of institutionalization of a good healthcare waste management system entails a waste assessment and evaluation of existing practices, evaluation of waste management options, development of a waste management plan, promulgation of institutional policies and guidelines, establishment of a waste management organization, allocation of human and financial resources, implementation of plans according to a set timelines, a program of periodic training, monitoring, evaluation, and continuous improvement.

The compendium outlines a process of technology selection based on UNEP's Sustainable Assessment of Technologies (SAT) methodology. The process begins with defining the scope of the problem, obtaining baseline data, and conducting stakeholder consultations. This is followed by a strategic level assessment, verification of facility-specific data, a screening process to eliminate generic technologies that do not meet basic criteria, a scoping analysis to generate a shorter list of potential technologies, a detailed technical and economic assessment to rank technologies, and a review of results to select the top treatment technologies. The compendium is intended to assist national and local governments, health organizations, and other stakeholders in developing countries in assessing and selecting appropriate technologies for the destruction of healthcare waste.

There are four basic processes involved in the treatment of healthcare waste: thermal, chemical, irradiative, and biological processes. Low-heat thermal technologies operate between 100°C and 180°C and can take place in either moist or dry heat environments. Moist (or wet) thermal treatment is the main process in medical waste autoclaves, hybrid autoclave systems, continuous steam treatment systems, batch and continuous microwave technologies, and frictional heat treatment systems. High-heat thermal processes operate at temperatures above 850°C and result in chemical and physical changes in the waste, which also result in the generation of products of incomplete combustion in the air emissions and ash. These high-heat thermal processes are used in incineration, pyrolysis, and gasification. Chemical treatment processes use chemical agents to destroy pathogens in the waste. A special case of a chemical process is the alkaline hydrolysis system that uses heated alkali to digest tissues, pathological waste, anatomical parts or contaminated animal carcasses. Infectious waste can also be treated using irradiative processes, such as those found in electron beam, Cobalt-60, and UV-C irradiation, but there are no commercial healthcare waste treatment technologies using primarily irradiative processes as of this writing. Biological processes refer to the natural degradation of organic matter. In addition to burial of

anatomical waste, composting and vermiculture have been used successfully to decompose hospital kitchen waste, organic digestible waste and placenta waste, but are not sold as commercial technologies as of this writing.

The compendium provides detailed process descriptions and information on types of waste treated, ranges of capacities, pathogen destruction, emissions, operational details, installation requirements, and maintenance needs for ten generic treatment technologies: autoclaves, hybrid autoclaves, continuous steam treatment, batch microwave, continuous microwave, frictional heat treatment, dry heat treatment, incineration and related technologies, alkaline hydrolysis, and chemical treatment systems. For developing countries, specific consideration has to be given to environmental and occupational safety aspects, social aspects and job potential, investment and operating costs, and institutional and regulatory requirements. The pros and cons of the ten generic technologies are compared and examples of specific application are given.

A major portion of the compendium deals with specific technologies. The inclusion of specific technologies does not constitute an endorsement by UNEP but is intended as a resource for the reader. Although a comprehensive survey is conducted, the compendium does not necessarily present a complete list. A total of 65 specific technologies are included, of which 47 are non-incineration technologies, not including 8 chemical-based technologies, plus 10 incineration technologies that reportedly meet international emission limits. The technologies in the list come from 22 countries: Argentina (1), Australia (3), Austria (2), Belgium (2), Canada (1), China (3), France (5), Germany (2), Hungary (1), India (2), Iran (1), Israel (2), Italy (4), Japan (2), Luxemburg (1), New Zealand (1), Philippines (1), Spain (2), Tanzania (1), Turkey (1), United Kingdom (3), and United States (24). The specific technologies described in detail include 15 autoclave technologies, 11 hybrid autoclaves, 4 continuous steam treatment systems, 3 batch microwave units, 3 continuous microwave systems, 2 frictional heating treatment technologies, 2 dry heat units, 10 incinerators, 4 alkaline hydrolysis technologies, 3 chemical treatment systems, and 8 additional technologies that are relatively new or emerging technologies within their geographical regions.

A description of the application of the UNEP SAT methodology is provided along with examples.

## I. INTRODUCTION

---

### 1 INTRODUCTION TO HEALTHCARE WASTE

---

#### 1.1 DEFINITIONS

Healthcare waste can be defined as all the waste generated by healthcare facilities, medical laboratories and biomedical research facilities, as well as waste from minor or scattered sources such as home health care.<sup>1</sup> Another commonly used definition of healthcare waste is: any waste, hazardous or not, generated during the diagnosis, treatment or immunization of humans or animals; or waste generated in research related to the aforementioned activities; or waste generated in the production or testing of biologicals.<sup>2</sup>

#### 1.2 SOURCES OF HEALTHCARE WASTE

Some regulations define healthcare waste as waste generated by hospitals, clinics, biomedical laboratories and other specific sources associated with human or animal health care. Below is a list of known and potential sources of healthcare waste:

- Hospitals, medical centers, and polyclinics
- Clinics, diagnostic facilities, dialysis centers and other specialized outpatient treatment facilities
- Primary health centers, rural health stations, basic health units, or health posts
- Maternity centers or birthing facilities
- Physicians' offices
- Dental clinics and offices
- Medical laboratories, biomedical laboratories and research centers, biotechnology laboratories, nuclear medicine laboratories
- Blood banks, blood collection centers, and blood transfusion centers
- Nursing homes for the elderly, long-term residential care facilities for the chronically ill, and hospices for the terminally ill
- Pharmacies and dispensaries, drug stores, pharmaceutical manufacturing facilities
- Alternative medicine treatment facilities (e.g., acupuncture centers)
- Veterinary hospitals, veterinarians' clinics, and veterinary offices
- Animal research and testing centers, and animal quarantine stations
- Home health care settings
- Health facilities, infirmaries, clinics, or health stations in colleges and universities, children's schools and summer camps, military establishments, police stations, prisons, and commercial or industrial establishments
- Emergency service facilities (ambulance stations, paramedic units, rescue operations)
- Coroners' or medical examiners' facilities, forensic pathology or autopsy laboratories, and crime laboratories
- Drug addiction rehabilitation centers
- Funeral homes and mortuaries
- Tattoo and cosmetic ear piercing establishments
- Health and quarantine stations in airports, ports, and immigration/customs facilities
- First-aid posts.

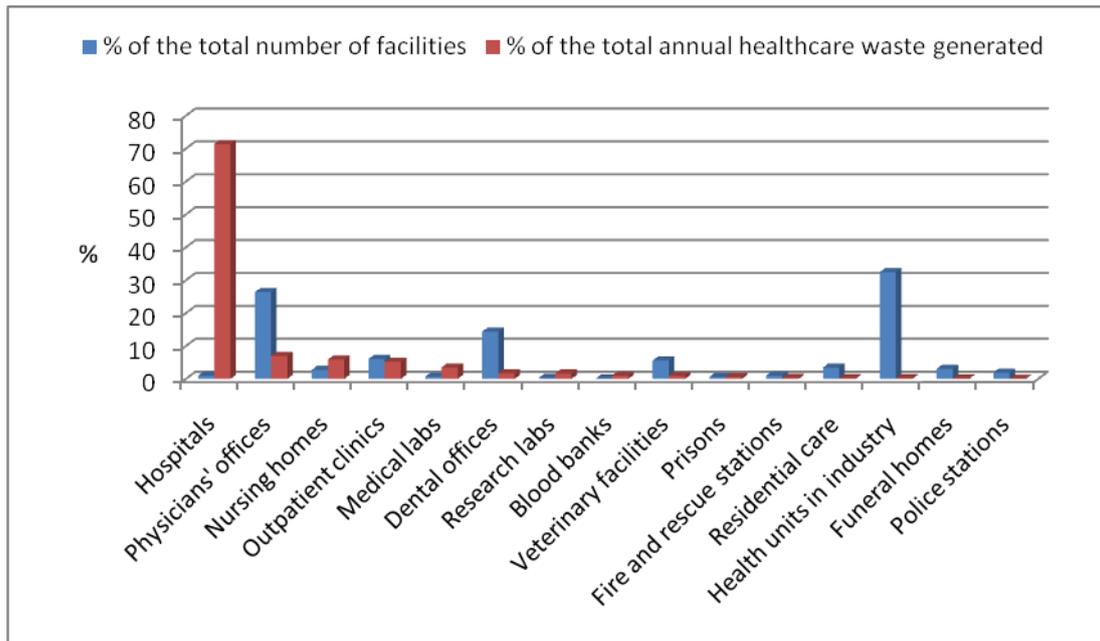
The bulk of healthcare waste is generally produced by hospitals. Health-related facilities in the United States can be categorized according to 15 types of sources. Hospitals, which comprise only 1% of all health-related facilities, account for 71% of the total healthcare waste generated annually. Doctors' offices, nursing homes,

---

<sup>1</sup> Adapted from Chapter 2, "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

<sup>2</sup> See, for example, definitions in the "Bio-medical Waste (Management and Handling) Rules," Second Amendment, Ministry of Environment and Forests, India, 2000.

clinics, and medical labs—which together make up 36% of the total facilities—contribute 22% of the healthcare waste (see Figure 1).<sup>3</sup>



*Figure 1.1 Typical Contributions of Different Health Facilities to Total Healthcare Waste Generated*

The pattern shown in Figure 1.1 above is expected in most countries, in which large hospitals produce the majority of healthcare waste even though they account for a small percentage of healthcare establishments, while small health centers, clinics, primary health stations, doctors' offices, etc. comprise the majority of health facilities but produce a smaller portion of the total healthcare waste stream. Although it is effective to focus initially on waste management practices in hospitals, the large number of primary health facilities should not be ignored.

<sup>3</sup> "Medical Waste Incinerators—Background Information for Proposed Guidelines: Industry Profile Report for New and Existing Facilities," EPA-453/R-94-042a, U.S. Environmental Protection Agency, Washington, DC, 1994.

---

## 2 HEALTH AND ENVIRONMENTAL IMPACTS OF HEALTHCARE WASTE

---

Various reports have highlighted the dangers of improper disposal of healthcare waste. A systematic review of healthcare waste management in 40 low- and middle-income countries revealed substantial problems in urban regions in Africa, Asia, and the Middle East exacerbated by increasing quantities of healthcare waste and improper treatment and disposal. The study noted that in addition to the deleterious health effects of incinerator emissions and ash, many incinerators were antiquated and dysfunctional and, as a consequence, infectious waste was often discarded with municipal waste or openly burned.<sup>4</sup>

A study by the World Health Organization (WHO) on the hazards of healthcare waste concluded that in developing countries where the waste is discarded without treatment in open dump sites, the health impacts are significant due to scavenging, the lack of personal protective equipment among waste workers, and the limited availability of immunization.<sup>5</sup> In Pakistan, scavenger boys sorting through medical waste for collection and resale experienced on average three to five needle-stick injuries a day.<sup>6</sup> In Mexico City, an interview of 69 sanitation workers revealed that 34% experienced between one to five needle-stick injuries in the previous year and 96% reported seeing needles and syringes in the waste.<sup>7</sup> At Sadr City Hospital in Iraq, a pediatrician reported dozens of children admitted with symptoms of infectious diseases due to contact with waste, including hospital waste.<sup>8</sup> A study that included field work in Pakistan and Bangladesh concluded that the urban poor are potentially at the greatest risk, in particular, waste pickers involved in collecting recyclables for selling to recycling establishments.<sup>9</sup>

As part of WHO's Global Burden of Disease Project, Prüss-Ustün *et al.* estimated that in the year 2000, about 16,000 hepatitis C infections, 66,000 hepatitis B infections, and 1,000 HIV infections may have occurred worldwide among healthcare workers due to occupational exposure to sharps injuries.<sup>10</sup> Among the recommended primary preventive measures is the proper management of sharps waste.

Another impact of healthcare waste on health and the environment relates to the use of old or poorly functioning medical waste incinerators that do not meet international standards. A medical waste incinerator releases a wide variety of pollutants including particulate matter such as fly ash; heavy metals (arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, etc.); acid gases (hydrogen chloride, hydrogen fluoride, sulfur dioxides, nitrogen oxides); carbon monoxide; and organic compounds like benzene, carbon tetrachloride, chlorophenols, trichloroethylene, toluene, xylenes, trichloro-trifluoroethane, polycyclic aromatic hydrocarbons, vinyl chloride, etc.<sup>11</sup> Pathogens can also be found in the solid residues and in the exhaust of poorly designed and badly operated incinerators.<sup>12</sup> In addition, the bottom ash residues are generally contaminated with leachable organic compounds, such as dioxins, and heavy metals and have to be treated as hazardous waste.

---

<sup>4</sup> M.O. Harhay, S.D. Halpern, J.S. Harhay and P.L. Olliaro, *Tropical Medicine and International Health* **14** (11), 1414–1417 (2009).

<sup>5</sup> I.F. Salkin and M.E. Kennedy, "Review of Health Impacts From Microbiological Hazards in Health-Care Waste," World Health Organization, Geneva, Switzerland, 2001.

<sup>6</sup> A. Altaf and S.A. Mujeeb, "Unsafe disposal of medical waste: a threat to the community and environment," *Journal of the Pakistan Medical Association*, **52** (6), 232 (2002).

<sup>7</sup> B. Thompson, P.L. Moro, K. Hancy, I.R. Ortega-Sánchez, J.I. Santos-Preciado, C. Franco-Paredes, B.G. Weniger, and R.T. Chen, "Needlestick injuries among sanitation workers in Mexico City," *Rev Panam Salud Publica* **27** (6), 467–468 (2010).

<sup>8</sup> Integrated Regional Information Networks, "Iraq: Medical waste a growing health hazard," April 2007.

<sup>9</sup> J. Appleton and M. Ali, "Healthcare or Health Risks? Risks from Healthcare Waste to the Poor," WELL (Water and Environmental Health at London and Loughborough), Water Engineering and Development Centre, Loughborough University, Leicestershire (2000).

<sup>10</sup> A. Prüss-Ustün, E. Rapiti, and Y. Hutin, *American Journal of Industrial Medicine* **48** (6), 482–490 (2005).

<sup>11</sup> J. Emmanuel, "Best Environmental Practices and Alternative Technologies for Medical Waste Management," presented at the Eighth International Waste Management Congress and Exhibition, Kasane, Botswana, June 25–28, 2007.

<sup>12</sup> M. Barbeito and M. Shapiro, "Microbiological Safety Evaluation of a Solid and Liquid Pathological Incinerator," *J. Medical Primatology*, **6**:264–273, 1977; S. Klafka and M. Tierney, "Pathogen Survival at Hospital/Infectious Waste Incinerators," *Proceedings: National Workshops on Hospital Waste Incineration and Hospital Sterilization*, EPA Office of Air Quality Planning and  
(footnote continued)

A health risk assessment study of small-scale incinerators was commissioned by the World Health Organization and completed in January 2004.<sup>13</sup> The study looked at how small-scale incinerators are operated in the field and their reported emissions of dioxins and furans. Based on this, the study identified three classes: (1) incinerators as “best practice,” operated and maintained properly using sufficient temperatures, afterburners, and other features to limit concentrations of dioxins; (2) incinerators as “expected practice,” that is, improperly designed, constructed, operated and maintained; and (3) “worst-case” incinerators that have no afterburners. The WHO study stipulated three operating scenarios: (1) “low usage” equivalent to 12 kg/month or 1 hour of operation per month; (2) “medium usage” equivalent to 24 kg/week or 2 hours of operation per week; and (3) “high usage” or 24 kg/day or 2 hours of operation per day. The emissions and usage rates were used to estimate uptake rates of dioxins and furans for adults and children via ingestion, and compared them to WHO’s provisional tolerable intake rate (1-4 pg TEQ/kg-day) and an exposure level (0.001 pg TEQ/kg-day) based on the upper bound of US EPA’s cancer potency factor for dioxins and furans. The study concluded that ingestion intake rates and carcinogenic risks were unacceptable for the “worst-case” incinerators even at low usage rates. For the “expected usage” incinerators, the low usage rates kept intake below the WHO provisional intake levels but de minimis risks based on US EPA’s cancer potency factor were exceeded. Similarly, de minimis cancer risks were exceeded by the “best practice” incinerators at the highest usage.

Studies investigating the relationship between human exposures to incinerator emissions and the occurrence of health effects in local populations have been difficult, in part because of confounding factors—especially in distinguishing the contribution of incineration versus other pollutant sources—and the complications in measuring highly variable environmental concentrations. In a study of school children living near a wire-reclamation incinerator in Taiwan, Wang *et al.* concluded that the high air pollution levels in the area near the incinerator were associated with a detrimental effect on lung function in the children.<sup>14</sup> Zmirou *et al.* concluded that the purchase of respiratory medication decreased as the distance of residences from incinerators increased.<sup>15</sup> In contrast, Gray *et al.* did not find an adverse effect on the prevalence or severity of childhood asthma among children within a 6-km radius of a sewage sludge incinerator in Sydney, Australia.<sup>16</sup> In a study by Shy *et al.*, no difference was found in acute or chronic respiratory symptoms or lung functions between communities adjacent to medical waste and municipal waste incinerators, and comparison groups away from the incinerators.<sup>17</sup> These conflicting results illustrate the complexity of conducting epidemiological studies of the health impacts of incineration in local populations and the need to increase the power of epidemiological studies by looking at multi-site studies.<sup>18</sup>

Despite the uncertainties and at times contradictory results, especially with regards to acute and chronic respiratory disorders, more and more studies in the last two decades indicate a clear association between exposure to incinerator emissions and increased body burdens and adverse health impacts. Various studies in Japan, Spain, and Germany show that incinerator workers or children and other residents living near incinerators have significantly higher blood or urine levels of dioxins, furans, polychlorinated biphenyls, hexachlorobenzene, 2,4/2,5-dichlorophenols, 2,4,5-trichlorophenols, hydroxypyrene, toluene, and tetrachlorophenols compared to control groups or to national averages.<sup>19</sup> Similar studies show a higher prevalence of urinary mutagen and

---

Standards, EPA-450/4-89-002, January 1989; *Hospital Medical Waste Incinerator Operation and Maintenance*, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 1989.

<sup>13</sup> “Assessment of Small-Scale Incinerators for Health Care Waste,” S. Batterman, report prepared for the Protection of the Human Environment, World Health Organization, Geneva, January 21, 2004.

<sup>14</sup> J.Y. Wang, T.R. Hsiue, and H.I. Chen, *Arch. Dis. Child.* 67(4): 488-490, 1992.

<sup>15</sup> D. Zmirou, B. Parent, and J.-L. Potelon, *Rev. Epidem. Sante Publ.* 32:391-397, 1984.

<sup>16</sup> E.J. Gray, J.K. Peat, C.M. Mellis, J. Harrington, and A.J. Woolcock, *Aust. New Zealand J. Medicine* 24(2): 168-175, 1994.

<sup>17</sup> C.M. Shy *et al.*, *Environmental Health Perspectives* 103(7-8): 714-724, 1995.

<sup>18</sup> *Waste Incineration and Public Health*, Committee on Health Effects of Waste Incineration, National Research Council, Washington, D.C.: National Academy Press, 2000.

<sup>19</sup> S. Kumagai and S. Koda, *J. Occupational Environmental Hygiene*, 2(2): 120—125, (February 2005); S. Kumagai, S. Koda, T. Miyakita and M. Ueno, *Occupational Environmental Medicine* 59: 362-368 (2002); K. Kitamura, Y. Kikuchi, S.

Watanabe, G. Waechter, H. Sakurai, and T. Takada, *Journal Epidemiology* 10(4): 262-270 (2000); C. Gonzalez, M.

Kogevinas, E. Gadea, A. Hulci, A. Bosch, M. Bleda, and O. Papke, *Arch. Environ. Health* 55: 259-267 (2000); A. Schecter,

H. Miyata, S. Ahta, O. Aozasa, T. Nakao, and Y. Masuda, *Organohalogen Compounds* 44: 247-250 (1999); H. Miyata, S.

Kuriyama, T. Nakao, O. Aozasa, and S. Ohta, *Organohalogen Compounds* 38: 143-146 (1998); B. Holdke, W. Karmaus and

H. Kruse, *Die Gesundheitswesen* 60 (8-9): 505-512 (1998); A. Schecter *et al.*, *Occup. Environ. Medicine*, 52, 385-387 (1995); R.

(footnote continued)

promutagen levels in incinerators workers.<sup>20</sup> Studies in Finland, Germany and the United States show higher levels of mercury in the hair, of cadmium and lead in the blood, of arsenic in urine among incinerator workers or residents living closer to incinerators.<sup>21</sup>

Epidemiological studies indicate an association between incineration and cancer. Studies in the United Kingdom found an increased risk of childhood cancer, childhood leukemia, and solid tumors of all kinds among children living near incinerators.<sup>22</sup> Studies in France, Japan, Italy, United Kingdom, and Sweden found a cluster of soft tissue sarcoma and non-Hodgkin's lymphoma; a two-fold cancer risk; increases in laryngeal cancer; increases in lung cancer or lung cancer mortality; and generally higher risks of all cancers but specifically of stomach, colorectal, liver, and lung cancer among populations living near incinerators.<sup>23</sup> Incinerator workers in Italy, U.S., and Sweden had significantly higher gastric cancer mortality; a high prevalence of hypertension and related proteinuria; and excessive deaths from lung cancer and ischemic heart disease.<sup>24</sup> A systematic review by Porta *et al.* found limited evidence of an increased risk of cancer for population living within three kilometers of old incinerators, with a higher confidence in the estimated excess risk for non-Hodgkin's lymphoma and soft tissue sarcoma.<sup>25</sup>

Associations have also been found between incineration and reproductive or developmental disorders or genetic anomalies. A study in the U.K. found increased risk of lethal congenital anomalies, in particular, spina bifida and heart defects, with mothers living close to incinerators; and an increased risk of stillbirths and anencephalus among mothers living around crematoria.<sup>26</sup> A study in Belgium found incidences of congenital malformation and a statistically significant increase in multiple pregnancies among residents born in a neighborhood between two incinerators.<sup>27</sup> Another study in the U.K. found an increased frequency of twinning among residents in areas at most risk from incinerator emissions.<sup>28</sup> Children near an incinerator in Germany showed hormonal effects as determined by blood thyroid hormone levels.<sup>29</sup>

On July 2011, the Special Rapporteur of the United Nations Human Rights Council presented his report at the UN General Assembly on the adverse effects of unsound management and disposal of medical waste which, he concluded, impacted the human rights of a significant number of people including medical staff, patients, workers in support services, workers in waste disposal facilities, recyclers, scavengers, and the general public. He called on "all relevant stakeholders, including States, international organizations and mechanisms, the donor community, public and private health-care facilities, the pharmaceutical industry and civil society to strengthen their efforts to achieve safe and sustainable management of medical waste."<sup>30</sup>

---

Wrbitzky *et al.*, *Int. Arch. Occup. Environ. Health*, 68, 13-21 (1995); J. Angerer *et al.*, *Int. Arch. Occup. Environ. Health*, 64, 266-273 (1992); A.J. Schecter, R. Malkin, O. Papke, M. Ball, and P.W. Brandt-Raul, *Med. Sci. Res.* 19: 331-332 (1991);

<sup>20</sup> X.F. Ma *et al.*, *J. Toxicol. Environ. Health*, 37, 483-494 (1992); J.M. Scarlett *et al.*, *J. Toxicol. Environ. Health*, 31, 11-27 (1990).

<sup>21</sup> P. Kurttio *et al.*, *Arch. Environ. Health*, 48, 243-245 (1998); R. Wrbitzky *et al.*, *Int. Arch. Occup. Environ. Health*, 68, 13-21 (1995); R. Malkin *et al.*, *Environ. Res.*, 59, 265-270 (1992).

<sup>22</sup> E. Knox, *International Journal of Epidemiology*, 29:391-397 (2000); E.G. Knox and E.A. Gilman, *J. Epidemiol. Community Health* 52: 716-726 (1998).

<sup>23</sup> J.-F. Viel, P. Arneux, J. Baverel and J.-Y. Cahn, *Am. J. Epidemiol.* 152: 13-19 (2000); H. Miyata, S. Kuriyama, T. Nakao, O. Aozasa, and S. Ohta, *Organohalogen Compounds* 38: 143-146 (1998); P. Michelozzi *et al.*, *Occup. Environ. Med.*, 55, 611-615 (1998); A. Biggeri *et al.* *Environ. Health Perspect.*, 104, 750-754 (1996); P. Elliott *et al.*, *Br. J. Cancer*, 73, 702-710 (1996); P.J. Diggle, *J. R. Stat. Soc. A* 153: 349-362 (1990); P. Gustavsson, *Am. J. Ind. Medicine*, 15, 129-137 (1989).

<sup>24</sup> E. Rapiti *et al.*, *Am. J. Ind. Medicine*, 31, 659-661 (1997); E.A. Bresnitz *et al.*, *Am. J. Ind. Medicine*, 22, 363-378 (1992); P. Gustavsson, *Am. J. Ind. Medicine*, 15, 129-137 (1989).

<sup>25</sup> D. Porta, S. Milani, A.I. Lazzarino, C.A. Perucci and F. Forastiere, "Systematic review of epidemiological studies on health effects associated with management of solid waste," *Environmental Health* 8:60, (2009).

<sup>26</sup> T. Drummer, H. Dickinson and L. Parker, *J. Epidemiological Community Health*, 57, 456-461 (2003).

<sup>27</sup> N. Van Larebeke, proceedings of the seminar "Health Impacts of Waste Management Policies," Hippocrates Foundation, Kos, Greece, 12-14 November 1998.

<sup>28</sup> O.L. Lloyd *et al.*, *Br. J. Ind. Medicine*, 45, 556-560 (1988).

<sup>29</sup> N. Osius and W. Karmaus, *Die Gesundheitswesen* 60: 107-112 (1998).

<sup>30</sup> C. Georgescu, "Report of the Special Rapporteur on the adverse effects of the movement and dumping of toxic and dangerous products and wastes on the enjoyment of human rights," A/HRC/18/31, Human Rights Council, 18<sup>th</sup> Session, United Nations General Assembly, July 4, 2011.

The WHO policy on healthcare waste management points out that poorly managed healthcare waste exposes healthcare workers, waste handlers and the community to infections. Moreover, in developing countries, small incinerators present a health risk due to the release of dioxins, furans and other toxic pollutants in the air emissions and in the ash. The WHO policy calls for, among others, the promotion of new technologies or alternative to small-scale incineration.<sup>31</sup>

### Incinerators and Dioxin/Furan Emissions<sup>32</sup>

Incinerators and other sources release dioxins and furans into the air, ash, and water. Dioxins and furans (herein referred to simply as “dioxins”) are a family of 210 compounds of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, including the most toxic, namely, 2,3,7,8-tetrachloro-dibenzo-p-dioxin or 2,3,7,8-TCDD. Dioxins are transported in the atmosphere and are capable of being transported thousands of kilometers away across national boundaries.

Dioxins are removed from the atmosphere via wet or dry deposition onto surface water, soil or vegetation. Dioxins in soil tend to adsorb strongly to organic matter. Estimates of the environmental half-life of TCDD on soil range from 9 to 15 years on the soil surface, and 25 to 100 years in subsurface soil.<sup>33</sup> The half-life of dioxins in sediment depends on many factors including aerobic biodegradation and the extent to which sediment is re-suspended in the water. The transformation reaction half-life of 2,3,7,8-TCDD in sediment has been estimated to range from 1.6 to 9.9 years.<sup>34</sup>

Dioxins are readily bioaccumulated and move up the food chain. The bioconcentration factor (BCF) is the ratio of the concentration in an organism over the concentration in water. For example, the BCF of 2,3,7,8-TCDD in fish exposed for 71 days has been measured at 128,000 for fathead minnows and 66,000 for carp.<sup>35</sup> For terrestrial animals, the BCF is the concentration of dioxin in the tissue of the animal divided by the concentration in food. Researchers estimated BCF for human adipose tissue as between 104 to 206.<sup>36</sup> The biological half-life of dioxins in the human body is between 5.8 to 11.3 years.<sup>37</sup>

Animal studies indicate that toxicological effects of dioxins take place at extremely low concentrations. For example, the lowest observable adverse effect levels for increase abortions, endometriosis, decreased off-spring survival, and other adverse effects on Rhesus monkeys are in the order of 0.00065 microgram per kilogram body weight per day.<sup>38</sup>

TCDD has been classified a carcinogen by the International Agency for the Research of Cancer. Dioxin has been linked to chronic lymphocytic leukemia, soft-tissue sarcoma, non-Hodgkin's lymphoma, and Hodgkin's disease.<sup>39</sup> There is limited or suggestive evidence of a possible association with respiratory cancer, prostate cancer, type 2 diabetes, spina bifida in children of exposed persons, and other disorders. Other possible health

<sup>31</sup> “Policy Paper: Safe health-care waste management,” World Health Organization, Geneva, Switzerland, August 2004.

<sup>32</sup> J. Emmanuel, “New Guidelines on Best Available Techniques for Medical Waste Incineration under the Stockholm Convention,” presented at the Eighth International Waste Management Congress and Exhibition, Kasane, Botswana, June 25-28, 2007.

<sup>33</sup> D.J. Paustenbach, R.J. Wenning, V. Lau, *et al.*, *J. Toxicol. Environ. Health* 36(2), 103-150, 1992.

<sup>34</sup> D. Hsieh *et al.*, “Intermedia Transfer Factors for Contaminants Found in Hazardous Waste Sites: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD),” Final Draft Report, Department of Toxic Substances Control and California Environmental Protection Agency, December 1994.

<sup>35</sup> P. Cook, D. Kuehl, M. Walker, *et al.*, “Bioaccumulation and toxicity of TCDD and related compounds in aquatic ecosystems,” in *Banbury Report 35: Biological basis for risk assessment of dioxins and related compounds*, M. Gallo, J. Scheuplein, and J. Van Der Heijden (Eds.), Plainview, NY: Banbury Center Meeting Cold Spring Harbor Laboratory Press, 1991.

<sup>36</sup> H. Geyer *et al.*, *ibid.*

<sup>37</sup> J. Olson, “Pharmacokinetics of dioxin and related compounds,” in *Dioxin and Health*, A. Schechter (Ed.), New York, NY: Plenum Press, p. 163-167, 1994; J. Pirkle, W. Wolfe, D. Patterson, *et al.*, *J. Toxicol. Environ. Health* 27, 165-171, 1989.

<sup>38</sup> “Toxicological Profiles for Chlorinated Dibenzo-p-Dioxins,” Agency for Toxic Substances and Diseases Registry, Atlanta, Georgia, December 1998.

<sup>39</sup> *Veterans and Agent Orange: Update 2002*, Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides (Fourth Biennial Update), Institute of Medicine, Washington, DC: The National Academies Press, 2003.

effects associated with chronic dioxin exposures include reproductive disorders such as reduced sperm count and decreased fertility, as well as developmental and immune system impacts.<sup>40</sup> Human exposure to dioxins is primarily through ingestion of meat, fish, and dairy products. The U.S. Environmental Protection Agency (US EPA) estimates a cancer potency factor of 0.001 picograms TEQ per kilogram per day.<sup>41</sup>

Dioxins are unintentionally produced during incineration of wastes through *de novo* synthesis, wherein carbon, hydrogen, oxygen, and chlorine recombine and react to form dioxins as the exhaust gases cool in a critical temperature range from between 450 to 250 °C.<sup>42</sup> Dioxins are also formed through a precursor route, involving surface-catalyzed reactions of chlorinated precursors such as chlorobenzenes and chlorophenols. These precursors are byproducts of incomplete combustion typically at temperatures of around 750 °C.<sup>43</sup> The reactions are catalyzed by elements in the fly ash. Both organic and inorganic chlorine in the waste provide the chlorine source for dioxin formation. When released from incinerator stacks, dioxins are primarily adsorbed on airborne particulates.

Dioxins are also found in incinerator ash. Various studies have reported that a significant portion of the dioxins formed in an incinerator are in the ash or slag. Abad and co-workers, for example, found that an average of 33% of dioxins is in the ash of a municipal waste incinerator.<sup>44</sup> Based on studies of German incinerators, Huang and Buekens found 4.3% of dioxins in the bottom ash.<sup>45</sup> Giugliano *et al.* found 22% and 72.6% of dioxins in the slag of two incinerators.<sup>46</sup> For this reason, incinerator ash should be disposed of as hazardous waste.

---

### 3 PURPOSE OF THE COMPENDIUM

---

This compendium is intended to assist national and local governments, health organizations, and other stakeholders in developing countries in assessing and selecting appropriate technologies for the destruction of healthcare waste. The compendium reviews data on healthcare waste, recommends qualitative factors and estimation parameters pertaining to healthcare waste, presents an overview of generic treatment technologies, and provides detailed information on specific technologies.

The focus of the compendium is on treatment and destruction technologies and not on other aspects of healthcare waste management. Nevertheless, it is essential that the technologies are integrated with the whole healthcare waste management system. Thus, the compendium provides a brief overview of healthcare waste management, which is not intended to be a comprehensive presentation.

---

<sup>40</sup> N. Weisglas-Kuperus, S. Patandin, G. Berbers, *et al.*, *Environ Health Perspect* 108(12):1203-1207, 2000; Technical Support Document: The American People's Dioxin Report, Center for Health, Environment and Justice, Falls Church, VA, November 1999; "Toxicological Profiles for Chlorinated Dibenzo-*p*-Dioxins," Agency for Toxic Substances and Diseases Registry, Atlanta, Georgia, December 1998; A. Mayani, S. Barel, S. Soback, and M. Almagor, *Human Reprod.* 12(2):373-375, 1997; L. Birnbaum, *Environ Health Perspect.* 103(suppl 2):157-160, 1995; N. Weisglas-Kuperus, C. Koopman-Esseboom, *et al.*, *Pediatr. Res.* 38:404-410, 1995; C. Koopman-Esseboom, D. Morse, N. Weisglas-Kuperus, *et al.*, *Pediatr. Res.* 36(4):468-473, 1994; S. Rier, D. Martin, R. Bowman, *et al.*, *Fund. Appl. Toxicol.* 21:433-441, 1993; T. Mably, R. Moore, R. Peterson, *Toxicol. Appl. Pharmacol.* 114:97-107, 1992; and S. Schantz and R. Bowman, *Neurotoxicol. Teratol.* 11(1):13-19, 1989.

<sup>41</sup> "Part II. Health Assessment for 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD) and Related Compounds," Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, 2001.

<sup>42</sup> L. Stieglitz and H. Vogg, *Chemosphere* 16, 1917-1922, 1987.

<sup>43</sup> K. Froese and O. Hutzinger, *Environ. Sci. Tech.* 28(7), 998-1008, 1996.

<sup>44</sup> E. Abad, M. Adrados, J. Caixach, B. Fabrellas and J. Rivera, *Chemosphere* 40(9-11), 1143-1147, May-June 2000.

<sup>45</sup> H. Huang and A. Buekens, *Chemosphere* 31(9), 4099-4117, November 1995.

<sup>46</sup> M. Giugliano, S. Cernuschia, M. Grossoa, E. Aloigib and R. Migliob, *Chemosphere* 43(4-7), 743-750, May 2001; M. Giugliano, S. Cernuschia, M. Grossoa, R. Migliob and E. Aloigib, *Chemosphere* 46(9-10), 1321-1328, March 2002.

## II. BASIC DATA ON HEALTHCARE WASTE

### 4 CONSTITUENTS AND OTHER BASIC PROPERTIES OF HEALTHCARE WASTE

#### 4.1 MATERIAL CONSTITUENTS OF HEALTHCARE WASTE

The material constituents of healthcare waste are mainly paper and other cellulosic materials, plastics, glass, metal, and food waste, with a small percentage of pathological waste (anatomical or body parts, tissues, organs, etc.) and placenta from child birth. Table 4.1 compares average material constituents of healthcare waste in six countries. Note however that the data came from different studies that used different methodologies. As shown later, about 85% of healthcare waste is non-risk (non-hazardous) general waste. In general, more than half of general waste from hospitals is paper, cardboard, and plastics, and the rest is food, metal, glass, cloth, wood, and other types of solid waste. Some have estimated that plastics could be as high as 60% especially in developed countries.<sup>47</sup> Food waste accounted for 12 to 17% in the six countries but could be as high as 25%.<sup>48</sup> If properly segregated, most general waste from healthcare facilities is recyclable or compostable. Determining the material constituents of general waste is important when setting up recycling programs.

Table 4.1. Average Material Constituents of Healthcare Waste<sup>49</sup>

Jordan*		Peru		Turkey		Taiwan		Kuwait		Italy	
Constituent	%	Constituent	%	Constituent	%	Constituent	%	Constituent	%	Constituent	%
Paper	38	Mixed paper	22	Paper	16	Paper	34	Paper	24	Paper	34
		Cardboard	5	Carton	5			Cardboard	8	Cardboard	8
Plastic	27	Plastic	12	Plastic	41	Plastic	26	Plastic	18	Plastics	46
Glass	10	Glass	8	Glass	7	Glass	7	Glass	10	Glass	8
Metals	5			Metal	2	Metal	4	Metal	9	Metal	0.4
				Food	17	Food	15	Food	12		
Textiles	11	Cotton/gauze	18	Textiles	10	Textiles	9	Textiles	11		
		Placenta	8							Anatomical	0.1
Garbage	9	Other	27	Other	3	Other	3	Other	8	Liquids	12

\* excluding kitchen waste

An in-depth study on waste was conducted by the Health Care Foundation Nepal (HECAF) at Bir Hospital in Kathmandu for an entire year from 2011 to 2012. The hospital recycled paper, plastic and metal from the non-infectious waste stream as well as plastic materials recovered from autoclaved syringe barrels. The hospital also treated biodegradable waste using an on-site anaerobic digester to generate biogas for local energy needs. Data on recyclable waste is shown in Table 4.2. The material constituents of recyclable waste are shown in Figure 4.1.<sup>50</sup>

Table 4.2. Data on Recyclable Healthcare Waste from a Low-Income Country (Nepal)

	Total recycled waste	Plastic	Paper	Glass	Metal
Kg/bed-day	0.134	0.066	0.045	0.017	0.005
% of total waste	25.2	12.4	8.5	3.3	1.0

Source: Data from Mahesh Nakarmi, HECAF, 2012.

<sup>47</sup> See Table 2.9 in C.R. Brunner, *Medical Waste Disposal*, ICI, Reston, Virginia, 1996.

<sup>48</sup> Megha Rathi (consultant, India) and Ruth Stringer (Health Care Without Harm), personal communication, 2012.

<sup>49</sup> A.R. Awad *et al.*, *Journal of Environmental Science and Health*, Part A, 39:2, 313-327 (2005); "Diagnostico situacional del manejo de los residuos solidos de hospitales administrados per el Ministerio de Salud," Ministerio de Salud, Direccion General de Salud Ambiental, Lima, Peru, (1995); S. Altin *et al.*, *Polish Journal of Environmental Studies*, 12(2): 251-255 (2003); L. Chih-Shan and J. Fu-Tien, *Infection control and hospital epidemiology*, 14(3):145-150 (1993); H.M. Hamoda *et al.*, *Journal of Environmental Science and Health*, A40:467-476 (2005); L. Liberti *et al.*, *Waste management and research*, 12(5): 373-385 (1994).

<sup>50</sup> Mahesh Nakarmi (HECAF) and Ruth Stringer (Health Care Without Harm), personal communication, 2012.

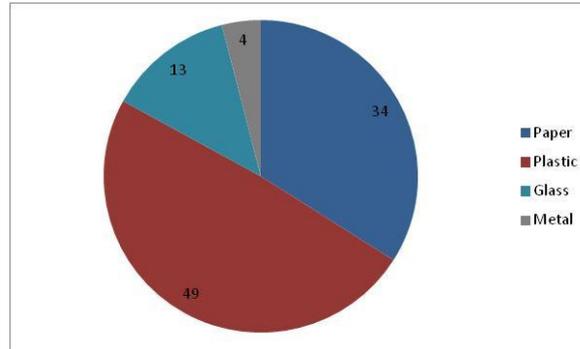


Figure 4.1. Material Constituents of Recyclable Waste in a Low-Income Country

When conducting a waste assessment of material constituents, however, it is important to do the analysis according to the different departments or services of the healthcare facility. Figure 4.2 shows the variability in material constituents for several departments of an 863-bed research and teaching hospital. For comparison, the material constituents of segregated infectious waste for the same departments of a 1000-bed research and teaching hospitals are shown in Figure 4.3. For minor sources such as private family practice clinics and dental facilities, the material constituents of segregated infectious waste are presented in Figure 4.4.

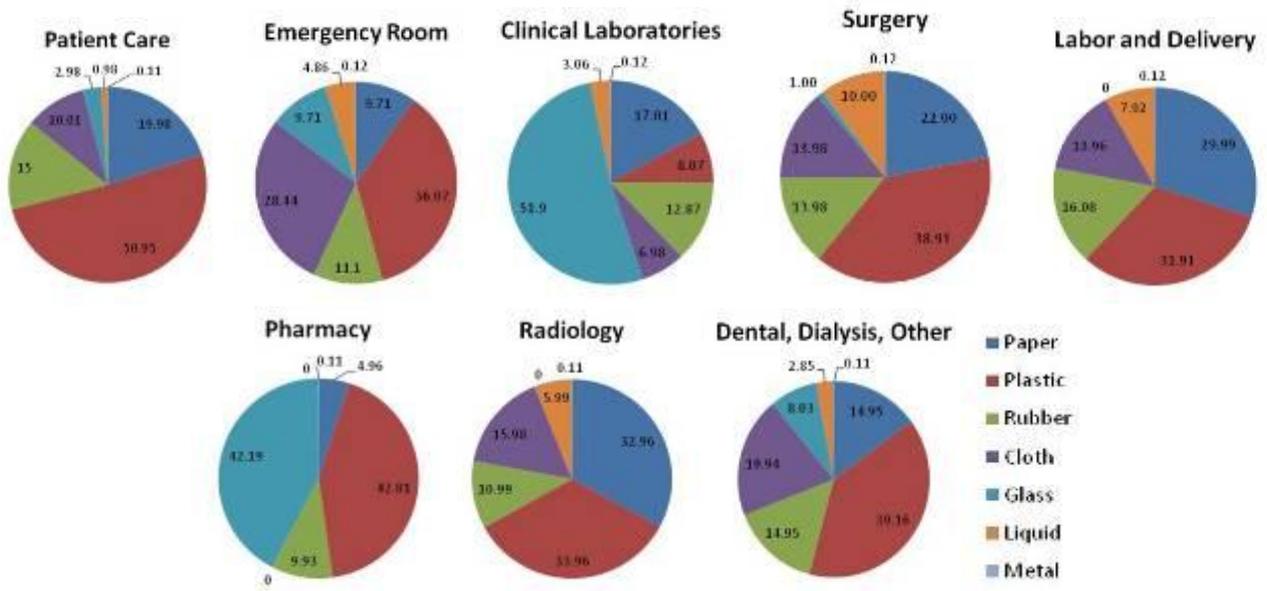


Figure 4.2. Material Constituents of Healthcare Waste in Several Departments of a Large Hospital<sup>51</sup>

<sup>51</sup> D. Hansell *et al.*, “Medical Waste Characterization,” report prepared by the Energy and Environmental Research Group (Irvine, California) for the U.S. Environmental Protection Agency, 1991.

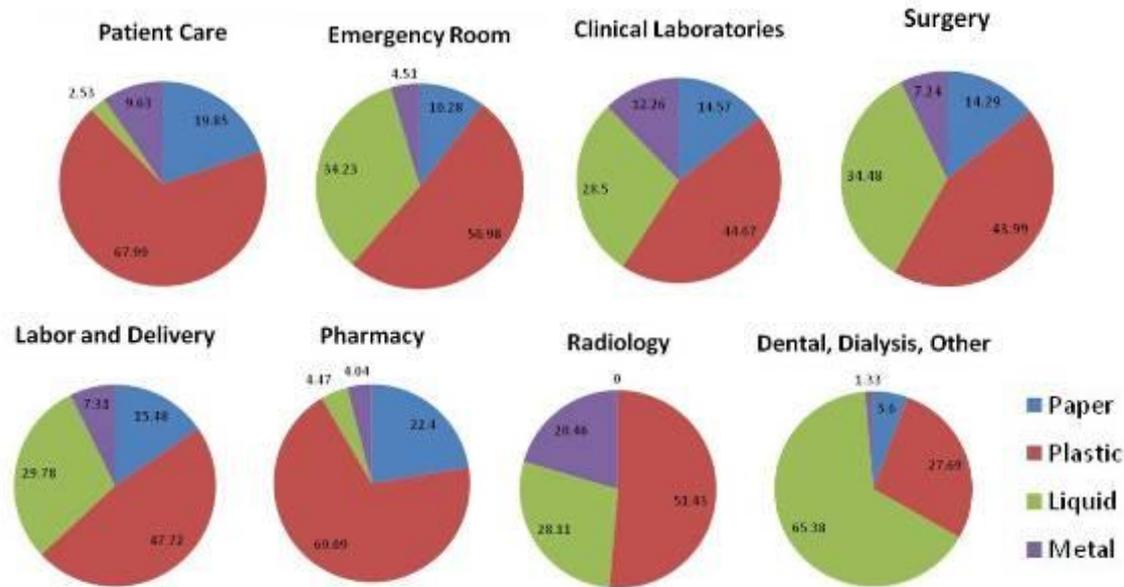


Figure 4.3. Material Constituents of Infectious Waste in Several Departments of a Large Hospital<sup>52</sup>

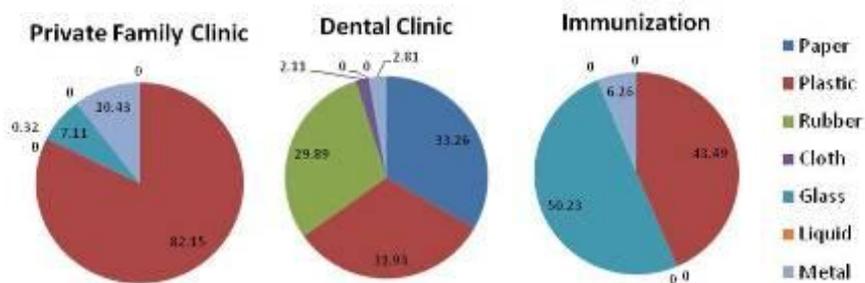


Figure 4.4. Material Constituents of Infectious Waste in Small Healthcare Facilities<sup>53</sup>

In addition to material constituents, other properties of healthcare waste are needed for evaluating suitable treatment technologies, developing equipment specifications or establishing operating parameters for treatment. For example, some steam or microwave treatment systems depend on the amount of moisture in the waste, some chemical systems are affected by the organic load and moisture level, and the combustion process is influenced by the percent combustibles, heating value, and moisture content of the waste. Information is provided below on the moisture content, percent combustible material, heating value, basic chemical composition, and bulk densities of healthcare waste. Two other essential parameters—waste classifications and generation rates—will be discussed in the next sections.

#### 4.2 MOISTURE CONTENT OF HEALTHCARE WASTE

The moisture content varies considerably depending on the composition of the waste. Healthcare waste from a 1900-bed hospital in Italy had an average moisture level of 26.76%, with a standard deviation of 8.48 based on 409 samples.<sup>54</sup> Some departments, such as obstetrics, pediatrics, and dialysis, have moisture levels as high as 50%. The waste from four hospitals in Turkey had an average moisture content of 14.15%.<sup>55</sup> The moisture content of different components of healthcare waste and specifically of infectious waste is shown in Table 4.2 based on data from four countries.

<sup>52</sup> D. Hansell *et al.*, *ibid.*

<sup>53</sup> D. Hansell *et al.*, *ibid.*

<sup>54</sup> L. Liberti *et al.*, *ibid.*

<sup>55</sup> S. Altin *et al.*, *ibid.*

Table 4.2. Percent Moisture Content of Healthcare Waste Constituents<sup>56</sup>

Overall healthcare waste				Infectious waste		
Constituent	Ecuador	Constituent	Jordan	Turkey	Component	Canada
Paper/cardboard	16	Paper	22-57	4.5	Human anatomical	70-90
Food	45	Food		63	Plastics	0-1
Textile	30	Textile	37-68	8.6	Swabs, absorbents	0-30
Plastic/Rubber	15	Plastic	11-54	2.8	Alcohol, disinfectants	0-0.2
Kitchen waste	47	Garbage	37-57		Animal infected anatomical	60-90
Garden wastes	40	Carton		5	Glass	0
Medicines	64	Metal		2.25	Bedding, shavings, paper, fecal mat.	10-50
		Glass		2.05	Gauze, pads, swabs, garments, paper, cellulose	0-30
		Others		8	Plastics, PVC, syringes	0-1
					Sharps, needles	0-1
					Fluid, residuals	80-100

#### 4.3 PERCENT INCOMBUSTIBLES IN HEALTHCARE WASTE

The average percentage of incombustibles was found to be about 8% at four hospitals in Turkey.<sup>57</sup> Others have estimated the incombustibles as 20.4% by weight of hospital waste.<sup>58</sup> The percentages of ash and other residues from infectious hospital waste, based on 409 samples from a large hospital in Italy, were: 66% at 100°C, 15% at 550 °C, and 14% at 1000 °C.<sup>59</sup>

#### 4.4 HEATING VALUE OF HEALTHCARE WASTE

The heating value of infectious healthcare waste ranged from a lower heating value of 3525 kcal/kg [14.8 MJ/kg] for wet waste and 5370 kcal/kg [24.0 MJ/kg] for dry waste.<sup>60</sup> The ranges of heating values for specific healthcare waste components are given in Table 4.3. Healthcare waste components that present problems for incineration because of the low heating values include: needles, blood and body fluids, full urine containers, IV bags, microscopic slides, slide covers, used vaccine vials, heavily wetted items, and body parts.<sup>61</sup>

Table 4.3. Heating Values of Various Healthcare Waste Components<sup>62</sup>

Component	Heating value (as fired)	
	MJ/kg	Kcal/kg
Human anatomical	2 – 8.4	400 – 2000
Plastics	32 – 46	7700 - 11000
Swabs, absorbents	13 – 28	3100 – 6700
Alcohol, disinfectants	25 – 32	6100 – 7800
Animal infected anatomical	2 – 15	500 – 3600
Glass	0	0
Bedding, shavings, paper, fecal matter	9 – 19	2200 – 4500
Gauze, pads, swabs, garments, paper, cellulose	13 – 28	3100 – 6700
Sharps, needles	0 – 0.1	0 – 30
Fluid, residuals	0 - 5	0 - 1100

<sup>56</sup> L.F. Diaz *et al.*, *Waste Management* 28 (7), 1219-1226 (2008); A.R. Awad *et al.*, *ibid*; S. Altin *et al.*, *ibid*; “Incinerator Design and Operating Criteria, Volume II, Biomedical Waste Incineration,” Ontario Ministry of the Environment, Ontario, Canada, 1986.

<sup>57</sup> S. Altin *et al.*, *ibid*.

<sup>58</sup> D. Campbell, “Hospital Waste Management in Canada,” Proceedings of the National Workshops on Hospital Waste Incineration and Hospital Sterilization, San Francisco, California, 1988; published in EPA-450-4-89-002, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, January 1989.

<sup>59</sup> L. Liberti *et al.*, *ibid*.

<sup>60</sup> L. Liberti *et al.*, *ibid*.

<sup>61</sup> D. Hansell *et al.*, *ibid*.

<sup>62</sup> Based on T. Milburn, “Biomedical Waste Incineration BACT Application Considerations,” Proceedings of the Third National Symposium on Infectious Waste Management, Chicago, Illinois, April 1989; cited in R. Barton *et al.*, “State of the Art Assessment of Medical Waste Thermal Treatment,” Energy & Environmental Research Corporation, Irvine, California, 1989.

#### 4.5 CHEMICAL COMPOSITION OF HEALTHCARE WASTE

Chemical composition along with heating value is used as a general guide to determine thermal treatability. Elemental compositions have been used to estimate the products of combustion but this can be misleading since healthcare waste varies widely and because persistent organic pollutants, such as polychlorinated dioxins and furans that are toxic at extremely low concentrations, cannot be predicted from basic elemental compositions.

Liberti *et al.* measured the carbon, hydrogen, oxygen, nitrogen, and sulfur composition of hospital waste using combustion (or pyrolysis in the case of oxygen analysis) followed by gas chromatography.<sup>63</sup> Infectious hospital waste samples were also tested for metals and some halogens. Seeker did an ultimate analysis using uncontrolled emission data from field tests to estimate the chemical compositions.<sup>64</sup> The results of these two separate studies are shown in Table 4.4.

As noted earlier, plastics comprise a significant portion of healthcare waste and the source of high caloric value. However, as much as 40% of plastic waste in modern hospitals is chlorinated plastics. Decreasing the percentage of halogenated plastics (such as polyvinyl chloride) reduces the amounts of hydrogen chloride and other halogenated pollutants emitted during combustion. Unfortunately, many polyvinyl chloride products, such as intravenous bags, tubing, gloves, and enteral feeding sets, are not labeled. Other common plastics in healthcare waste are low density polyethylene, high density polyethylene, polypropylene, polyethylene terephthalate, and polystyrene.

Table 4.4. Elemental Composition of Healthcare Waste

Analyte	From Seeker		From Liberti <i>et al.</i>
	General Waste	Infectious Waste	Infectious Waste
Carbon (%)	37 ± 4	40 ± 4.5	37
Hydrogen (%)	5.2 ± 0.4	6 ± 0.6	4.6
Oxygen (%)	8.6 ± 7	5 ± 4	18
Nitrogen (%)	0.08 ± 0.02	0.08 ± 0.01	0.99
Sulfur (%)	0.08 ± 0.02	0.00 ± 0.01	0.73
Chlorine (%)	1.8 ± 0.4%	2.8 ± 1.0	0.42
Moisture (%)	38 ± 8	37 ± 12	
Ash (%)	10 ± 2	10 ± 1.5	
Al (mg/kg)			3187
Zn (mg/kg)			1319
Fe (mg/kg)			938
Ba (mg/kg)			164
F (mg/kg)			82
Cu (mg/kg)			79
B (mg/kg)			66
Pb (mg/kg)			25
Br (mg/kg)			23
Sn (mg/kg)			18
Mn (mg/kg)			17
Cr+3 (mg/kg)			14
As (mg/kg)			10
Ni (mg/kg)			10
Sb (mg/kg)			6
Cr+6 (mg/kg)			2
Hg (mg/kg)			2
Tc (mg/kg)			2
Cd (mg/kg)			1
V (mg/kg)			0.5

Note: Data from Liberti *et al.* have been rounded off.

<sup>63</sup> L. Liberti *et al.*, *ibid.*

<sup>64</sup> W.R. Seeker, Chapter 5 in Environmental Management in Healthcare Facilities, Edited by K.D. Wagner, Philadelphia: W.B. Saunders Company, 1998; G.C. England et al., "Characterization of Emissions from Hospital Incinerators," Proceedings of the 1991 Incineration Conference, University of California, Irvine, California, 1991; G.C. England et al., "Characterization of Emissions from Hospital Incinerators," paper no. 92-40.03, 85<sup>th</sup> Annual Meeting of the Air & Waste Management Association, Kansas City, Missouri, 1992.

An analysis of toxic metals found in healthcare waste may give an indication of pollutant emissions. During combustion, some metals remain in the solid residue while others are volatilized or entrained in the flue gas and are either captured in the flue gas cleaning system or released to the atmosphere. Many heavy metals are readily emitted including lead, mercury, cadmium, arsenic, chromium, and zinc. Certain metals—such as copper, iron, zinc, sodium, and potassium—catalyze the formation of chlorinated dioxins and furans. Studies have shown that various plastics and rubber material used in health care are a source of metals (see Table 4.5).

#### 4.6 BULK DENSITY OF HEALTHCARE WASTE

Bulk density is the uncompacted mass per unit volume. It is used to estimate the required capacity needed for the treatment system if only either mass or volume is known. Bulk density is also used in estimating storage and transport capacities as well as specifications for compactors, shredders, and other size reduction equipment.

Different average bulk densities for healthcare waste have been reported: 594 kg/m<sup>3</sup> (urban hospitals, Tanzania); 218 kg/m<sup>3</sup> for total waste, 211 kg/m<sup>3</sup> for general waste, and 226 kg/m<sup>3</sup> for contaminated waste (hospitals, Peru); 151 kg/m<sup>3</sup> for general waste and 262 kg/m<sup>3</sup> for contaminated waste (urban hospitals, Philippines); and 110 kg/m<sup>3</sup> including boxes and 100 kg/m<sup>3</sup> without boxes (large hospital, Italy).<sup>65</sup> Table 4.6 gives bulk densities for different components of healthcare waste as measured in two countries.

Table 4.5. Metal Content of Healthcare Waste Components<sup>66</sup>

Component	Lead	Chromium	Cadmium	Arsenic
Orange autoclave plastic bag	+++++	++++		
Red plastic bag	++++	++++		
Latex glove	+	+		
Vinyl glove	+	+		
Blue rubber Vacutainer cap	+++	+++	++	+++
Gray rubber Vacutainer cap	+++	+++	++	+++
Green rubber Vacutainer cap	++	+++	++	+++
Lavander rubber Vacutainer cap	+++	+++	++	+++
Wall sharps container	++	+		
Winfield sharps container	++++	+++		
Sharps tray	+++++	++++		
Speculum				
Syringe, 10 cc	++	++	++	++
Syringe, 3 cc	++			
Syringe, 0.5 cc	++	++		
Syringe, 12 cc	++			
Paper towel	++	+		
Aerosol tubing		++		
Clear urine container	+++	+	+	
Red urine container		++		

Legend: + means 0.1 to <1 µg/g; ++ means 1 to <10 µg/g; +++ means 10 to <100 µg/g; ++++ means 100 to <1000 µg/g; +++++ means 1000 to <10,000 µg/g; and no symbol means the metal concentration is below the detection limit or only trace amounts were found.

Table 4.6. Bulk Densities of Healthcare Waste Components<sup>67</sup>

Canada		Ecuador	
Component	kg/m <sup>3</sup>	Component	kg/m <sup>3</sup>
Human anatomical	800-1200	General wastes	596.22
Plastics	80-2300	Kitchen wastes	322.19
Swabs, absorbents	80-1000	Yard wastes	126.25
Alcohol, disinfectants	800-1000	Paper/cardboard	65.14
Animal infected anatomical	500-1300	Plastic/rubber	85.35
Glass	2800-3600	Textiles	120.27
Bedding, shavings, paper, fecal matter	320-730	Sharps	429.11
Gauze, pads, swabs, garments, paper, cellulose	80-1000	Food wastes	580.19
Plastics, PVC, syringes	80-2300	Medicines	959.71
Sharps, needles	7200-8000		
Fluid, residuals	990-1010		

<sup>65</sup> Chapter 2 in “Safe management of waste from health-care activities,” World Health Organization, Geneva, Switzerland (upcoming edition).

<sup>66</sup> D. Hansell *et al.*, *ibid.*

<sup>67</sup> L.F. Diaz *et al.*, *Waste Management* 28 (7), 1219-1226 (2008); “Incinerator Design and Operating Criteria, Volume II, Biomedical Waste Incineration,” Ontario Ministry of the Environment, Ontario, Canada, 1986.

Healthcare waste has characteristics that are similar to those of municipal solid waste. However, healthcare waste generally has higher amounts in percent by weight of wet cellulosic solids and plastics, and has a higher heating value and slightly lower percent incombustibles compared to municipal solid waste.<sup>68</sup>

---

## 5 CLASSIFICATIONS AND COMPOSITION OF HEALTHCARE WASTE

---

As a general rule, between 75% and 90% of the waste produced by healthcare facilities is non-risk (non-infectious, non-hazardous) general waste, comparable to domestic waste. Only a small portion of healthcare waste is regarded as hazardous and may create health risks. Figure 5.1 shows a typical breakdown of waste from a healthcare facility.

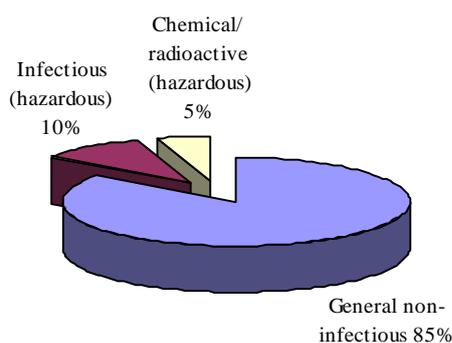


Figure 5.1. Typical Breakdown of Healthcare Waste<sup>69</sup>

Healthcare waste can be categorized according to the following general classifications: sharps waste, pathological waste, other infectious wastes, pharmaceutical waste including cytotoxic waste, hazardous chemical waste, radioactive waste, and general (non-risk) waste.<sup>70</sup> Descriptions and examples of each classification are provided in Table 5.1.

**Sharps wastes** are items that could cause cuts or puncture wounds. These including suture needles, hypodermic needles, scalpel and other blades, knives, infusion sets, saws, broken glass, and pipettes. Whether or not they are infected, these items are considered hazardous healthcare waste. Infected sharps may be considered a subcategory of infectious waste but are dealt with separately because of the significant risk associated with sharps injuries.

**Infectious waste** is waste that is suspected to contain pathogens (disease-causing bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts. The subcategories of infectious waste are (a) waste contaminated with blood or other body fluids; (b) microbiological cultures and stocks of infectious agents from laboratory work; and (c) waste from infected patients in isolation wards.

Waste contaminated with blood or other body fluids include: free-flowing blood, blood components, and other body fluids (semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid,

---

<sup>68</sup> D. Campbell, *ibid.*

<sup>69</sup> "Technical Guidelines on the Environmentally Sound Management of Biomedical and Healthcare Wastes (Y1; Y3)," Secretariat of the Basel Convention, United Nations Environment Programme, Châtelaine, Switzerland (2003).

<sup>70</sup> Chapter 2 in "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

peritoneal fluid, amniotic fluid, saliva and other body fluids visibly contaminated with blood); dressings, bandages, swabs, gloves, masks, gowns, drapes, and other material contaminated with blood or other body fluids; and waste that has been in contact with the blood of patients undergoing hemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns, aprons, gloves, and laboratory coats).

*Table 5.1. Summary of the Major Classifications of Healthcare Waste*

<b>Waste Classification</b>	<b>Description and Examples</b>
Sharps waste	Used or unused sharps e.g., hypodermic, intravenous or other needles; auto-disable syringes; syringes with attached needles; infusion sets; scalpels; pipettes; knives; blades; broken glass
Infectious waste	Waste suspected to contain pathogens (see section 2.1.2) e.g., waste contaminated with blood and other body fluids; laboratory cultures and microbiological stocks; waste from isolation wards; tissues (swabs), materials, or equipment that have been in contact with infected patients; excreta
Pathological waste	Pathological waste e.g., human tissues, organs or fluids; body parts; fetuses
Pharmaceutical waste, including cytotoxic waste	Pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals  Cytotoxic waste containing substances with genotoxic properties, e.g. waste containing cytostatic drugs (often used in cancer therapy); genotoxic chemicals
Chemical waste	Waste containing chemical substances, e.g. laboratory reagents; film developer; disinfectants that are expired or no longer needed; solvents; waste with high content of heavy metals, e.g., batteries; broken thermometers and blood-pressure gauges; pressurized containers
Radioactive waste	Waste containing radioactive substances, e.g. unused liquids from radiotherapy or laboratory research; contaminated glassware, packages, or absorbent paper; urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources
Non-risk general waste	Waste that does not pose a biological, chemical, radioactive, or physical hazard

Cultures and stocks of highly infectious agents, waste from autopsies, animal bodies, and other waste items that have been inoculated, infected, or in contact with such agents are highly infectious waste. Discarded instruments or materials that have been in contact with infected persons or animals are also considered infectious waste.

Waste from infected patients in isolation wards include excreta, dressings from infected or surgical wounds, and clothes heavily soiled with human blood or other body fluids.

Like infected sharps, **pathological waste** also could be considered a subcategory of infectious waste but is often classified separately since it requires special methods of handling, treatment and disposal. Pathological waste consists of tissues, organs, body parts, blood, body fluids and other waste from surgery and autopsies on patients with infectious diseases. It also includes human fetuses and infected animal carcasses. Recognizable human or animal body parts are also called anatomical waste. This category may include healthy body parts.

**Pharmaceutical waste** includes expired, unused, spilled, and contaminated pharmaceutical products, drugs, vaccines, and sera that are no longer needed. The classification also includes discarded items used in the handling of pharmaceuticals, such as bottles, boxes, gloves, masks, vials, and tubing contaminated with pharmaceutical residues.

**Genotoxic waste** may have mutagenic, teratogenic, or carcinogenic properties. They include certain cytostatic drugs, vomit, urine, or feces from patients treated with cytostatic drugs, chemicals, and radioactive material. Cytotoxic (chemotherapeutic or antineoplastic) drugs, the principal substances in this category, have

the ability to kill or stop the growth of certain living cells and are used in chemotherapy of cancer. Cytotoxic drugs are most often used in specialized departments such as oncology and radiotherapy units; their use in other hospital departments and outside the hospital setting is increasing.

**Chemical waste** consists of discarded solid, liquid, and gaseous chemicals, for example from diagnostic and experimental work and from cleaning and disinfecting procedures. Chemical waste from health care is considered to be hazardous if it has at least one of the following properties:

- toxic
- corrosive (e.g. acids of pH < 2 and bases of pH > 12)
- flammable
- reactive (explosive, water-reactive, shock-sensitive).

Nonhazardous chemical waste consists of chemicals with none of the above properties, such as sugars, amino acids, and certain organic and inorganic salts.

Example of hazardous chemical waste are: formaldehyde, glutaraldehyde, photographic fixers and developing solutions used in X-ray departments, spent solvents from laboratories and engineering departments, and wastes with high levels of metals such as mercury, cadmium, and lead.

**Radioactive waste** includes solid, liquid, and gaseous materials contaminated with radionuclides. The radionuclides can have short half-lives (in hours or days) or long half-lives (in months and years).

**General (non-risk) wastes** are similar to domestic waste. They can be further subcategorized as recyclable waste, compostable waste, and non-recyclable waste. Examples of common recyclable material found in healthcare waste include: corrugated cardboard boxes, white office paper, computer printout paper, newspapers, magazines, aluminum beverage cans, aluminum containers, food tin cans, other metal containers, polyethylene terephthalate (PET or PETE) plastic water bottles, PET soft drink bottles, high density polyethylene (HDPE) plastic milk containers, HDPE containers for food and mild solutions, polypropylene plastic bottles for saline solutions or sterile irrigation fluids, polystyrene packaging, clear glass, colored or mixed glass, wood, construction and demolition debris, and wood shipping pallets.<sup>71</sup>

Durable goods such as used furniture, bed frames, and curtains, as well as old computer equipment, printer cartridges, photocopying toners, etc. are potentially recyclable. Flowers, food waste, and yard waste are examples of compostable waste.

Table 5.2 gives specific examples under the major waste classifications according to departments in a hospital. Table 5.3 gives examples for minor sources.

*Table 5.2. Examples of Healthcare Waste in Departments of a Hospital According to Classification<sup>72</sup>*

Departments	Sharps	Infectious and pathological waste	Chemical, pharmaceutical and cytotoxic waste	General waste
Medical ward	Hypodermic needles, intravenous set needles; broken vials and ampoules	Dressings, bandages, gauze, and cotton contaminated with blood or body fluids; gloves and masks contaminated with blood or body fluids	Broken thermometers and blood pressure gauges; spilt medicines; spend disinfectants	Packaging, food scraps, paper, flowers, empty saline bottles, non-bloody diapers; non-bloody IV tubing and bags

<sup>71</sup> C.L. Bisson, G. McRae and H.G. Shaner, *An Ounce of Prevention: Waste Reduction Strategies for Health Care Facilities*, American Society for Healthcare Environmental Services, American Hospital Association, Chicago, Illinois, 1993.

<sup>72</sup> Chapter 2, "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

Operating theatre	Needles, IV sets, scalpels, blades, saws	Blood and other body fluids; suction canisters; gowns, gloves, masks, gauze, and other waste contaminated with blood and body fluids; tissues, organs, fetuses, body parts	Spent disinfectants	Packaging, uncontaminated gowns, gloves, masks, hats and shoe covers
Laboratory	Needles; broken glass, Petri dishes, slides and cover slips; broken pipettes	Blood and body fluids; microbiological cultures and stocks; tissue; infected animal carcasses; tubes and containers contaminated with blood or body fluid	Fixatives; formalin; xylene, toluene, methanol, methylene chloride, and other solvents; broken lab thermometers	Packaging; paper, plastic containers
Pharmacy store			Expired drugs; spilled drugs	Packaging, paper, empty containers
Radiology			Silver; fixing and developing solutions; acetic acid; glutaraldehyde	Packaging, paper
Chemotherapy	Needles and syringes		Bulk chemotherapeutic waste; vials, gloves and other material contaminated with cytotoxic agents; contaminated excreta and urine	Packaging, paper
Environmental services	Broken glass		Disinfectants (glutaraldehyde, phenols, etc.), cleaners, spilled mercury, pesticides	Packaging, flowers, newspapers, magazines, cardboard, plastic and glass containers, yard waste
Engineering			Cleaning solvents, oils, lubricants, thinners, asbestos, broken mercury devices, batteries	Packaging, construction or demolition waste, wood, metal
Food services				Food scraps; plastic, metal and glass containers; packaging

Table 5.3. Examples of Healthcare Waste From Minor Sources According to Classification<sup>73</sup>

Sources	Sharps	Infectious and pathological waste	Chemical, pharmaceutical and cytotoxic waste	General waste
Physicians' offices	Needles and syringes, broken ampoules and vials	Cotton, gauze, dressing, gloves, masks and other materials contaminated with blood or other body fluids	Broken thermometers and blood pressure gauges; expired drugs; spent disinfectants	Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks
Dental offices	Needles and syringes, broken ampoules	Cotton, gauze, gloves, masks and other materials contaminated with blood	Dental amalgam; spent disinfectants	Packaging, office paper, newspapers, magazines, uncontaminated gloves and masks
Home health care setting	Lancets and insulin injection needles	Bandages and other material contaminated with blood or other body fluids	Broken thermometers	Domestic waste

<sup>73</sup> Chapter 2, "Safe management of waste from health-care activities," WHO, *ibid.*

---

## 6 HEALTHCARE WASTE GENERATION RATES

---

Waste generation data are used in estimating the required capacities for containers, storage areas, transport, or treatment technologies. Waste generation data have been used to establish baselines and for procurement specifications, planning, budgeting, calculating revenues from recycling, optimization of waste management systems, and environmental impact assessments. They are also used for national assessments and national planning.

The following factors affect the rate of waste generation in healthcare facilities:

- level of activity (often measured in terms of the number of occupied beds plus number of outpatients per day, total number of patients per day, and/or number of staff); this is also linked to the average length of stay of patients which may reflect the intensity of care
- type of department (e.g., general ward, surgical theatre, office, etc.)
- type or level of facility (e.g., clinic, provincial hospital, etc.)
- location (rural or urban)
- regulations or policies on waste classification
- monitoring and enforcement by local or national authorities
- extent of use of disposable materials
- procurement policies
- segregation practices
- extent of recycling, inventory control and other waste minimization activities
- temporal variations (e.g., week day versus weekend, seasonal)
- level of development of the country.

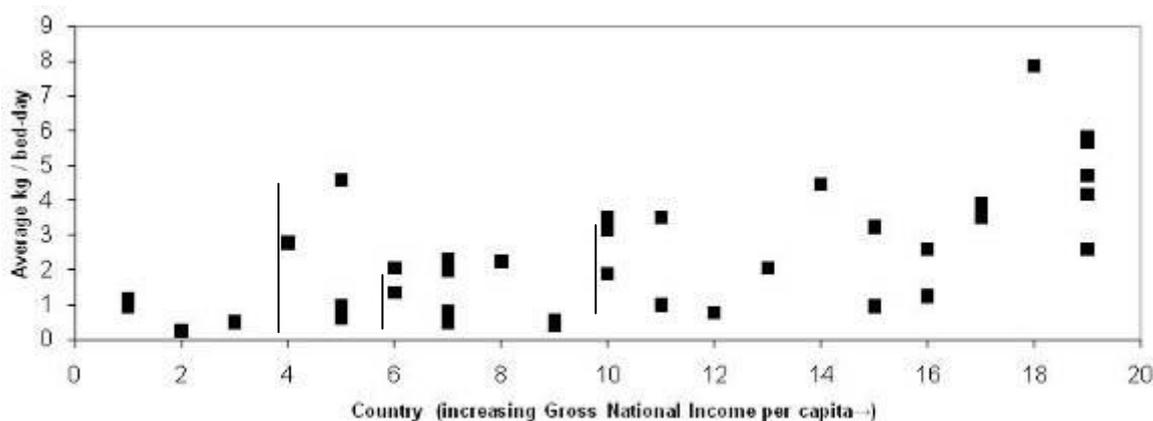
Variations in waste generation according to the type or level of facility, or between rural and urban, may reflect differences in services provided, scale, organizational complexity, availability of resources, and the number of medical and other staff. Regulations or policies on waste classification as well as segregation practices affect the breakdown of waste generation rates. Dissimilarities among low-, middle- and high-income countries may be partly due to differences in resources, services, established waste management systems, and the amount of single-use disposable items.

Ideally, average waste generation rates are calculated on a weekly basis to account for daily variations during the week and lower activities during weekends, but data are often given in kilograms (kg) per day or kg per year. Kilograms per occupied bed per day and kg per patient per day are used especially when comparing health facilities with different levels of activities. If inpatient occupancy rates and the daily number of outpatients are not available, the total number of beds is often used to estimate kg per bed per day.

The data in Figures 6.1 to 6.4 provided as indicative values of total healthcare waste generation rates and/or infectious waste generation rates for hospitals, clinics, health centers and dispensaries.<sup>74</sup> They show the wide variability of data both within and among countries.

---

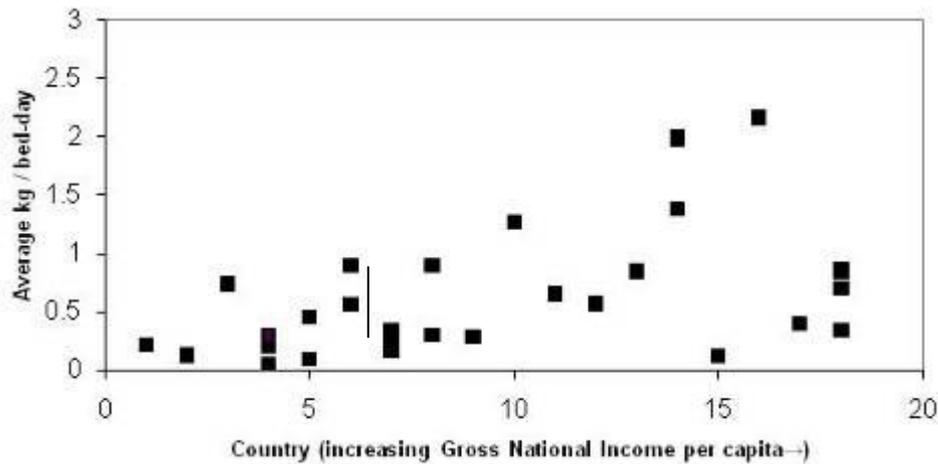
<sup>74</sup> Figures 6 and 7 are based on the data from the following: MSKA Sarkar et al., *ARPN Journal of Engineering and Applied Sciences*, Vol 1 No 2, August 2006; MH Rahman, 25th WEDC Conference on Integrated Development for Water Supply and Sanitation, Addis Ababa, Ethiopia, 1999; "Overview of the Management of Health Care Waste in the WHO's Western Pacific Region: Cambodia," WHO/WPRO, December 2003; S. Phengxay et al., *Waste Management & Research*, Vol. 23, No. 6, 571-581 (2005); BE Bassey et al., *African Health Sciences*, Vol. 6, No. 1, March, 2005, pp. 58-63; Diaz LF, Eggerth LL, Enkhtsetseg S, Savage GM., *Waste Manag.* 2007 Jul 23; "Current Situation of Healthcare Waste Management in Vietnam and 3R Application," N.T. Khoa, Department of Therapy, Ministry of Health, Hanoi, November 2005; MB Pescod and CB Saw, "Hospital Waste Management in Four Major Cities: A Synthesis Report," UWEP Working Document 8, Urban Waste Expertise Program, Netherlands, February 1998; CB Saw and T Hoo, "Management of hospital wastes and  
(footnote continued)



Points represent averages and lines represent ranges of data. Low-income countries: 1- Bangladesh (includes clinics), 2-Cambodia, 3-Lao PDR, 4-Nigeria, 5-Vietnam, 6-Pakistan, 7-India; Middle-income countries: 8-Guyana, 9-Philippines, 10-Jordan, 11-Columbia, 12-Peru, 13-Thailand, 14-Iran, 15-Brazil (includes health centers and labs), 16-Turkey; High-income countries: 17-Portugal, 18-Kuwait, 19-United States.

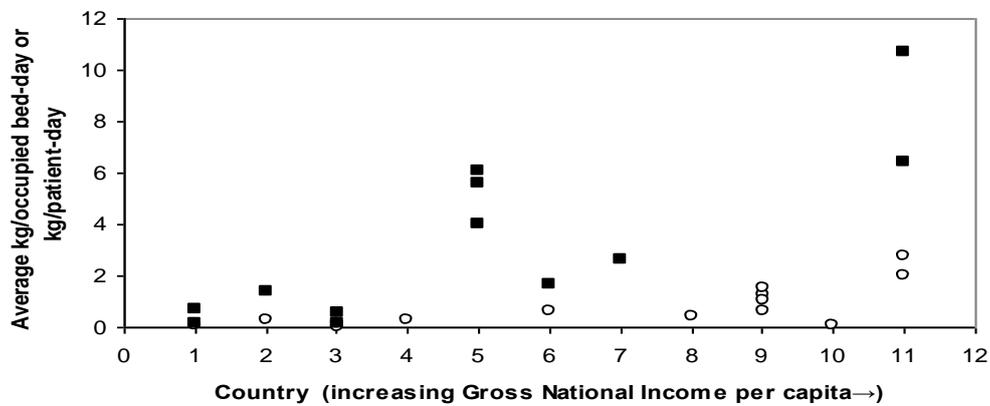
Figure 6.1. Total Healthcare Waste Generation Rates in Hospitals (in kg per bed per day)

associated risks to health,” WHO, WPRO, Manila, August 1998; Mahmood, Saqib Shahab, Raza Malik, Waqar Azim, Pakistan J Med Res Mar 2001;40(1):13-7; V. Visvanathan, Asia 3R Conference, Tokyo, Japan, 30 October-1 November 2006; GV Patil and K Pokhrel, Waste Management, Volume 25, Issue 6, 2005, Pages 592-599; SKM Rao et al., Medical Journal of Armed Forces India, 60, 379-382 (2004); AD Patil et al., J. Environ. Manag. 63, 211-220, 2001; some data from K Malviya, MSc dissertation “Existing Solid Waste Management from Hospitals,” Devi Alivya University, Indore; “Environmental Assessment Hospital Solid Waste Management in Guyana: Proposed HIV/AIDS/STD Control Project,” World Bank, January 2004; “Solid Waste Management in Cebu City,” 1st Thematic Seminar: Solid Waste Management, Kitakyushu, Japan, 19-20 September 2000; “Metro Manila solid waste management project [TA 3848-PHI]: Final report,” Vol. 8, Medical Waste Management, Asian Development Bank, 2003; A Bdour et al., Waste Management, Volume 27, Issue 6, 2007, Pages 746-759; AR Awad et al., Journal of Environmental Science and Health, Part A, Volume 39, Issue 2 January 2005, pages 315 – 327; Ministerio de Salud, 1995, as cited in Diaz LF et al., *ibid*; website using data from Ministerio de Salud - Dirección General de Salud Ambiental (DIGESA); Suwannee A. Study on waste from hospital and clinics in Phitsanulok. Online J Health Allied Scs. 2002; 3:3; M. Askarian et al., Waste Manag. 2004;24(4):347-52; National Audit Office, Ministry of Environment and Waters, Republic of Bulgaria, 2003-2004; A. Spasov, “Hospital Waste Management and Health-Ecological Risk Prophylaxis in Bulgaria,” National Center of Hygiene, Medical Ecology and Nutrition, Sofia, Bulgaria; presented at the 6th International Symposium and Exhibition on Environmental Contamination in Central & Eastern Europe and the Commonwealth of Independent States, Prague, Czech Republic, 1-4 September 2003; CE Da Silva et al., Waste Manag. 25, 600-605, 2005; CE da Silva et al., Waste Management, Volume 25, Issue 6, 2005, Pages 600-605; VDB Mattoso and V Schalch, Waste Management & Research, Vol. 19, No. 6, 567-572 (2001); S. Altin et al., Polish Journal of Environmental Studies, Vol 12 No 2, 251-255 (2003); CF Chiang et al., Infection Control and Hospital Epidemiology, volume 27 (2006), pages 519–522; M Alvim-Ferrz and S Alonso, Env Sci Tech 37, 14 (2003); “Plano estrategico dos residuos hospitalares,” Ministerios da Saude e do Ambiente, Lisboa, 1999; cited in Alonso, Env Sci Tech 37, 14 (2003); Data from Environmental Protection Department, The Government of the Hong Kong Special Administrative Region, no date; HM Hamoda et al., Journal of Environmental Science and Health, A40: 467-476 (2005); L. Liberti et al., Waste Management & Research, 12, 373-385, 1994; S. Sengupta, “Medical Waste Generation, Treatment and Disposal Practices in the State of Florida,” Florida Center for Solid and Hazardous Waste Management, University of Florida, Gainesville, FL, June 1990; WA Rutala et al., JAMA. 1989;262:1635-1640. Figures 8 and 9 are based on data from the above references as well as: RRAM Mato and ME Kaseva, Resources, Conservation and Recycling 25, 271-287 (1999); Sh. Enkhtsetseg et al., “Characterization study of healthcare wastes generated in Ulaanbaatar, Mongolia,” WHO, WPRO, Manila, Philippines (2005); G. Mehta, “Infection Control and Health Care Waste Management in the Kingdom of Bhutan: A Mission Report,” WHO Regional Office for Southeast Asia, May 2005; LF Diaz, “Manejo de residuos de establecimientos de salud en Guayaquil, Ecuador,” Pan American Health Organization, January 2001; “Projection for Health Care Risk Waste Generation,” DEAT Report Number 1219/6, Department of Environmental Affairs and Tourism, South Africa, 5 July 2006; R. Mohee, Waste Management, Volume 25, Issue 6, 2005, Pages 575-581.



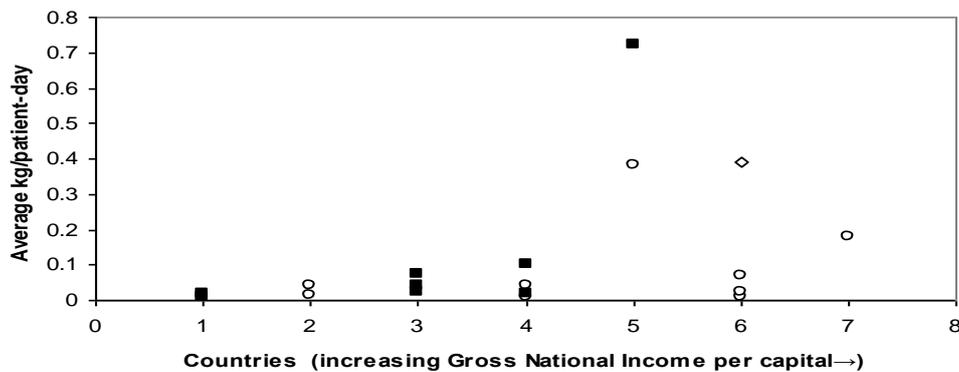
Points represent averages and lines represent ranges of data. Low-income countries: 1- Bangladesh (includes clinics), 2-Cambodia, 3- Nigeria (poor segregation of infectious waste), 4-Vietnam, 5-India; Middle-income countries: 6-Guyana, 7-Philippines, 8-Columbia, 9- Thailand, 10-Iran (poor segregation of infectious waste), 11-Bulgaria, 12-Brazil (includes health centers and labs, poor segregation of infectious waste), High-income countries: 13-Taiwan, 14-Portugal, 15-Hong Kong (China), 16-Kuwait (poor segregation of infectious waste), 17-Italy, 18-United States.

Figure 6.2. Infectious Waste Generation Rates in Hospitals (in kg per bed per day)



■ = total health-care waste; o = infectious waste. Low-income countries: 1- Tanzania, 2-Vietnam, 3-Mongolia; Middle-income countries: 4-Bhutan, 5-Jordan, 6-Ecuador, 7-Peru, 8-Bulgaria, 9-South Africa, 10-Mauritius; High-income countries: 11-United States.

Figure 6.3. Total and Infectious Waste Generation Rates in Hospitals (in kg per occupied bed per day or kg per patient per day)



■ = total health-care waste; o = infectious waste. Low-income countries: 1- Tanzania, 2-Bangladesh, 3-Pakistan, 4-Mongolia; Middle-income countries: 5-Ecuador, 6-South Africa, 7-Mauritius.

Figure 6.4. Total and Infectious Waste Generation Rates in Small Clinics, Health Centers, and Dispensaries (in kg per patient per day)

Table 6.5 provide data on total healthcare waste and infectious waste generation rates according to the type of facility based on data from three low-income countries.<sup>75</sup> Table 6.6 provides a breakdown according to type of facility for a two middle-income countries.<sup>76</sup> Table 6.7 has data for one high-income country.<sup>77</sup> Table 6.8 is based on national averages for total and infectious waste generation rates for hospitals in a high-income country based on the number of beds.<sup>78</sup>

*Table 6.5. Total and Infectious Healthcare Waste Generation Rates by Type of Facility for Low-Income Countries*

Type of facility	Total HCW generation	Infectious waste generation
Vietnam		
Central general hospital		0.3 kg/bed-day
Provincial general hospital – cities		0.25 kg/bed-day
Provincial general hospital – other provinces		0.20 kg/bed-day
Provincial/central special hospital		0.05 – 0.30 kg/bed-day
District/branch hospital		0.20 kg/bed-day
Community health centre		0.1 kg/bed-day
Pakistan		
Hospitals	2.07 kg/bed-day (range: 1.28-3.47)	
Clinics and dispensaries	0.075 kg/patient-day	0.06 kg/patient-day
Basic health units	0.04 kg/patient-day	0.03 kg/patient-day
Consulting clinics	0.025 kg/patient-day	0.002 kg/patient-day
Nursing homes	0.3 kg/patient-day	
Maternity homes	4.1 kg/patient-day	2.9 kg/patient-day
Tanzania		
Hospitals	0.14 kg/patient-day	0.08 kg/patient-day
Health centres (urban)	0.01 kg/patient-day	0.007 kg/patient-day
Rural dispensaries	0.04 kg/patient-day	0.02 kg/patient-day
Urban dispensaries	0.02 kg/patient-day	0.01 kg/patient-day

Sources: Pakistan data from 4 hospitals and other facilities in Karachi; Tanzania data based on a survey of facilities in Dar es Salaam.

*Table 6.6. Total and Infectious Healthcare Waste Generation Rates by Type of Facility for Middle-Income Countries*

Type of facility	Total waste generation	Infectious waste generation
South Africa		
National central hospital		1.24 kg/patient-bed-day
Provincial tertiary hospital		1.53 kg/patient-bed-day
Regional hospital		1.05 kg/patient-bed-day
District hospital		0.65 kg/patient-bed-day
Specialized hospital		0.17 kg/patient-bed-day
Public clinic		0.008 kg/patient-day
Public community health centre		0.024 kg/patient-day
Private day-surgery clinic		0.39 kg/patient-day
Private community health centre		0.07 kg/patient-day
Jordan		
Public hospital	6.10 kg/patient-day	
Maternity hospital	5.62 kg/patient-day	
Private hospital	4.02 kg/patient-day	
Government clinical laboratory	0.053-0.065 kg/test-day	
Private clinical laboratory	0.034-0.102 kg/test-day	

Note: In South Africa, clinics have no beds and may not be open all week; community health centers have up to 30 beds and operate 7 days a week. South Africa data are from a survey of 13 hospitals and 39 clinics in Gauteng and Kwa Zulu Natal; Jordan data from a survey of 4 hospitals and 10 clinical laboratories in Irbid, Jordan.

<sup>75</sup> “Current Situation of Healthcare Waste Management in Vietnam and 3R Application,” N.T. Khoa, Department of Therapy, Ministry of Health, Hanoi, November 2005; MB Pescod and CB Saw, “Hospital Waste Management in Four Major Cities: A Synthesis Report,” UWEP Working Document 8, Urban Waste Expertise Program, Netherlands, February 1998; Kaseva, Resources, Conservation and Recycling 25, 271-287 (1999); Christen J (1996). Dar es Salaam Urban Health Project. Health care waste management in district health facilities: situational analysis and system development. St. Gallen, Switzerland, Swiss Centre for Development Cooperation in Technology and Management (SKAT).

<sup>76</sup> “Projection for Health Care Risk Waste Generation,” DEAT Report Number 1219/6, Department of Environmental Affairs and Tourism, South Africa, 5 July 2006; A Bdour et al., Waste Management Volume 27, Issue 6, 2007, Pages 746-759; AR Awad et al., Journal of Environmental Science and Health, Part A, Volume 39, Issue 2 January 2005, pages 315 – 327.

<sup>77</sup> S. Sengupta, “Medical Waste Generation, Treatment and Disposal Practices in the State of Florida,” Florida Center for Solid and Hazardous Waste Management, University of Florida, Gainesville, FL, June 1990.

<sup>78</sup> WA Rutala et al., Journal of the American Medical Association. 1989;262:1635-1640.

Table 6.7. Total and Infectious Healthcare Waste Generation Rates by Type of Facility for a High-Income Country

Type of facility	Total HCW generation	Infectious waste generation
United States		
Metropolitan general hospitals	10.7 kg/occupied bed-day	2.79 kg/occupied bed-day
Rural general hospitals	6.40 kg/occupied bed-day	2.03 kg/occupied bed-day
Psychiatric and other hospitals	1.83 kg/occupied bed-day	0.043 kg/occupied bed-day
Nursing homes	0.90 kg/occupied bed-day	0.038 kg/occupied bed-day
Laboratories	7.7 kg/day	1.9 kg/day
Doctor's office (group practice, urban)	1.78 kg/physician-day	0.67 kg/physician-day
Doctor's office (individual, urban)	1.98 kg/physician-day	0.23 kg/physician-day
Doctor's office (rural)	0.93 kg/physician-day	0.077 kg/physician-day
Dentist's office (group practice)	1.75 kg/dentist-day	0.13 kg/dentist-day
Dentist office (individual)	1.10 kg/dentist-day	0.17 kg/dentist-day
Dentist office (rural)	1.69 kg/dentist-day	0.12 kg/dentist-day
Veterinarian (group practice, metropolitan)	4.5 kg/veterinarian-day	0.66 kg/veterinarian-day
Veterinarian (individual, metropolitan)	0.65 kg/veterinarian-day	0.097 kg/veterinarian-day
Veterinarian (rural)	7.7 kg/veterinarian-day	1.9 kg/veterinarian-day

Source: Survey of 37 hospitals, 41 nursing homes, 20 laboratories, 8 funeral homes, 41 doctors' offices, 64 dentists' offices and 17 veterinarians in Florida.

Table 6.8. Total and Infectious Healthcare Waste Generation Rates by Number of Hospital Beds for a High-Income Country

United States No. of hospital beds	Total waste		Infectious waste	
	kg/bed-day	kg/patient-day	% of total waste	kg/bed-day (calculated)
< 100	2.59	5.13	13.3	0.34
100-299	4.70	7.16	15.0	0.70
300-499	5.67	8.63	14.9	0.84
>500	5.83	.69	14.9	0.87
Total	4.18	6.93	15.0	0.63

In addition to Tables 6.5 and 6.6 which present data for low-income and middle-income countries, Table 6.9 gives an additional breakdown of waste generation (infectious waste excluding sharps, sharps waste, and general non-hazardous waste) by type of facility for a middle-income country in the 1990s.

Table 6.9. Breakdown of Infectious Waste Excluding Sharps, Sharps Waste and Regular Waste Generation Rates by Type of Facility for a Low- to Middle-Income Country<sup>79</sup> (see also Tables 6.5 and 6.5)

Type of facility	Infectious Waste excluding sharps (kg/day)	Sharps Containers (4 liter capacity each)	Regular (domestic) waste (kg/day)
Referral and regional hospitals	0.75 per bed	1.5 per 100 beds per day	3 per bed
Private hospitals	1 per bed	2 per 100 beds per day	4 per bed
Primary hospitals	0.5 per bed	1 per 100 beds per day	2 per bed
Urban clinics with beds	20	2 per 30 days	40
Rural clinics with beds	10	2 per 30 days	20
Urban clinics	15	2 per 30 days	30
Rural clinics	7	2 per 30 days	15
Health posts	2.5	1 per 30 days	5
Medical and veterinary practices	2.5	1 per 30 days	5

Source: Based on estimates of healthcare waste production from questionnaires sent to health facilities in Botswana in 1996 and visits in 1995-1998.

The in-depth study on waste at Bir Hospital in Nepal, conducted by the Health Care Foundation Nepal from 2011 to 2012, resulted in the data shown in Table 6.10 and Figure 6.5 below, based on waste segregated at the source and documented for an entire year.<sup>80</sup>

<sup>79</sup> "Study on the management of medical wastes," Report No. NCS/GTZ 7/96, National Conservation Strategy (Coordinating) Agency in cooperation with the German Agency for Technical Cooperation and coordinated by Integrated Skills Ltd., 1996; cited in "Safe management of waste from health-care activities," Edited by A. Prüss et al., World Health Organization, Geneva, Switzerland, 1999.

Table 6.10. Data on Healthcare Waste from a Low-Income Country (Nepal)

Total Healthcare Waste (kg/bed-day)	General Non-hazardous Non-biodegradable Waste (kg/bed-day)	Bio-degradable Waste (kg/bed-day)	Infectious Waste Including Sharps (kg/bed-day)	Hazardous Chemical / Pharmaceutical Waste (kg/bed-day)
0.533	0.256	0.147	0.120	0.009

Source: Data from Mahesh Nakarmi, HECAF, 2012.

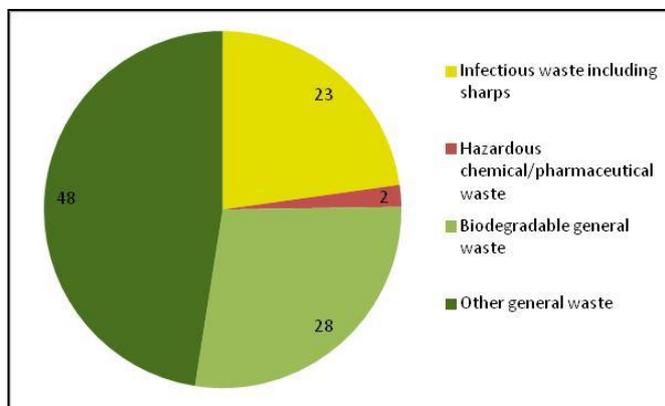


Figure 6.5. Healthcare Waste Data from a Low-Income Country

<sup>80</sup> Mahesh Nakarmi (HECAF) and Ruth Stringer (Health Care Without Harm), personal communication, 2012.

7 SUMMARY OF ESTIMATION FACTORS FOR HEALTHCARE WASTE

As much as possible, healthcare facility-specific waste assessment data should be used as a basis for detailed planning, budgeting, or procurement. A limited waste survey of the facility may provide more reliable data on waste generation than estimates based on indicative data from other countries or types of health facilities. However, in the absence of actual data obtained through waste assessments, indicative values may be used as factors for order-of-magnitude estimations. The following tables summarize factors for developing countries that could be used for estimation if actual data is not available.

It should be emphasized that these are *not* benchmark values but rather approximate figures that could be used for initial estimates where no data exist. Note that there is a large variability in the material constituents so a waste assessment is highly recommended if at all possible.

Table 7.1. Average Material Constituents of Healthcare Waste (excluding food waste)

Material Constituents	Composition Range (weight %)
Paper/carton	15 - 40
Plastics	10 - 60
Glass	5 - 15
Metal	1 - 10
Cloth/cotton/gauze	10 - 25
Other	5 - 25

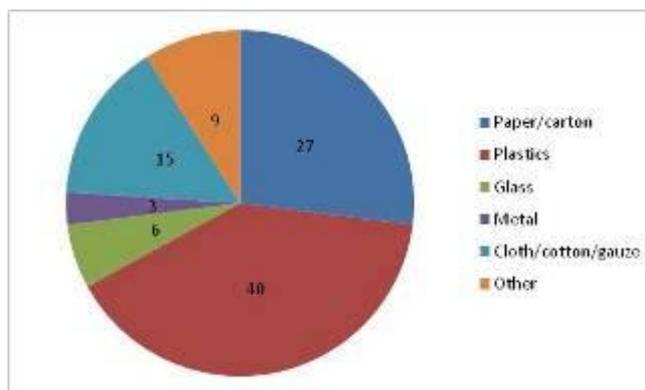


Figure 7.1. Average Material Constituents of Healthcare Waste (excluding food waste) in % weight

Table 7.2. Key Properties of Healthcare Waste

Parameter	Average Value
Moisture content	15% by weight
Heating value	15 MJ/kg (3600 kcal/kg or 6,400 BTU/lb)
Combustion residues	15% by weight
Bulk density	100 – 200 kg/m <sup>3</sup>

*Table 7.3. Typical Classifications Depending on Segregation Practice*

<b>Level of Segregation</b>	<b>% Hazardous Healthcare Waste</b>	<b>% General Non-Risk Waste</b>
Poor	60	40
Fair	25	75
Rigorous	15	85

*Table 7.4. Average Waste Generation Rates by Type of Facility*

<b>Facility</b>	<b>Total Healthcare Waste Generation Rate</b>	<b>Infectious Healthcare Waste Generation Rate</b>
Hospital	2 kg/bed-day	0.5 kg/bed-day
Clinic	0.02 kg/patient-day	.007 kg/patient-day
Maternity Center	5 kg/patient-day	3 kg/patient-day
Clinical Laboratory	0.06 kg/test-day	0.02 kg/test-day
Basic Health Unit	0.04 kg/patient-day	0.01 kg/patient-day

---

## 8 OVERVIEW OF HEALTHCARE WASTE MANAGEMENT

---

Even though this Compendium focuses on waste destruction technologies, it is important that treatment technologies are seen as an integral part of a healthcare waste management system which includes both best available technologies and best environmental practices. The basic elements of a healthcare waste management system include the following:<sup>81</sup>

- Waste classification
- Waste segregation
- Waste minimization
- Containerization
- Color coding
- Labeling and signage
- Handling
- Transport
- Storage
- Treatment
- Final disposal of waste.

The healthcare waste management system also includes:

- Initial and Refresher training
- Assessments and Planning
- Organization
- Budgeting
- Monitoring, Evaluation, and Continuous Improvement
- Documentation and Record-Keeping.

**Healthcare waste classifications** differ among countries but many are based on the WHO classifications. Segregation is key to efficient healthcare waste management. It entails the separation of different types of waste according to classifications at the point of generation. Segregating recyclable waste from other non-hazardous waste allows for significant waste minimization.

**Segregation** entails separating the waste into appropriate containers. 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.

**Color coding** is used for easy identification of different types of waste. Table 8.1 gives an example of a typical color coding scheme. In most countries, red or yellow bags are commonly used to designate infectious waste, while general waste is placed in black or clear bags. **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 in areas where both types of waste are generation result in better segregation. Too many infectious waste containers tend to inflate waste volume but too few containers may lead to noncompliance. Placing

---

<sup>81</sup> "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

infectious waste containers in areas where no infectious waste is generated (such as visitor waiting areas) or placing only general waste containers where infectious waste is produced results in improper segregation. Posters illustrating proper segregation displayed in areas where multiple containers are located serve as reminders to health workers.

*Table 8.1. Color Coding for Segregating Healthcare Waste*

Type of waste	Colour of container and markings	Type of container
Highly infectious waste	Yellow or red, marked "HIGHLY INFECTIOUS", with biohazard symbol	Strong, leak-proof plastic bag, or container capable of being autoclaved
Other infectious waste, pathological and anatomical waste	Yellow or red with biohazard symbol	Leak-proof plastic bag or container
Sharps	Yellow or red, marked "SHARPS" with biohazard symbol	Puncture-proof container
Chemical and pharmaceutical waste	Brown, labelled with appropriate hazard symbol	Plastic bag or container
Radioactive waste	labelled with radiation symbol	Lead box
General healthcare waste	Black or clear	Plastic bag

**Waste minimization** is the reduction, to the greatest extent possible, of waste that is destined for ultimate disposal. The potential benefits of waste minimization are: environmental protection, enhanced occupational safety and health, cost reductions, reduced liability, compliance with regulations, and improved community relations. The following are waste minimization techniques in order of decreasing preference:

- 1) Source reduction - minimizing or eliminating the generation of waste at the source itself; source reduction should have a higher priority than recycling or reuse. Some specific source reduction techniques include:
  - Material elimination, change or product substitution, e.g., substituting a non-toxic biodegradable cleaner for a cleaner that generates hazardous waste; or employing multiple-use instead of single-use products where appropriate
  - Technology or process change, e.g., using non-mercury-containing devices instead of mercury thermometers or mercury switches; using steam cleaning instead of chemical-based cleaners
  - Good operating practice, e.g., improving inventory control to reduce expired products; covering disinfecting solution trays to prevent evaporative losses; using the minimum formulation recommended for an application
  - Environmentally preferable purchasing such as selecting vendors with reduced packaging (see below).
  
- 2) Resource recovery, reuse, and recycling - some specific examples include:
  - Recycling newspapers, office paper, glass, aluminum cans, and other recyclables
  - Purchasing products made of post-consumer recycled material
  - Composting organic food waste
  - Recovering silver from photographic chemicals.

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.

Environmentally preferable purchasing (EPP) or the procurement of environmentally sound products is an important part of waste minimization. For example, EPP could mean procurement of products that do not contain polyvinyl chloride (PVC), mercury, highly toxic cleaners, excessive packaging, etc. In general, EPP addresses the life cycle of products brought into the facility and takes into account the toxicity of substances (such as cleaning solvents and disinfectants).

**Healthcare waste handling, collection and transport 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. Other best environmental practices include the collection of waste when 3/4ths full and the use of appropriate personal protective equipment.

**Storage** in designated storage areas is another element of healthcare waste management. 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.

A **healthcare waste management plan** describes 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 healthcare waste; (4) specific procedures for handling healthcare waste; and (5) training. The plan should be reviewed periodically and all staff members involved in healthcare waste should read it.

Healthcare 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 healthcare facility can be cleaned up using spill containment and cleanup kits. Plans and procedures should also be developed in response to exposure incidents such as needle-stick injuries.

The institutionalization of a good healthcare waste management system in a healthcare facility requires the following:

- Assessment of the waste stream and existing environmental practices
- Evaluation of waste management options
- Development of waste management plans
- Promulgation of institutional policies and guidelines which clearly define roles and responsibilities of personnel
- Establishment of a waste management organization
- Allocation of human and financial resources
- Implementation of plans
- Periodic training
- Monitoring, evaluation and continuous improvement.

The effective management of waste depends on good **healthcare waste management organization**. A waste management team or committee should be formed to develop and implement the waste management plan. The team should have the following members: head of the facility, heads of departments, infection control officer and/or hospital hygienist, chief pharmacist, radiation officer, head nurse, hospital manager, hospital engineer, financial controller, and waste management officer. In healthcare facilities in low-income areas, the minimum structure is an infection control committee with a person responsible of healthcare waste management.

**Budgeting** is another key issue. Recognizing that the sustainability of sound systems for healthcare waste management depends on the availability of resources, the WHO core principles for achieving safe and sustainable management of healthcare waste require that all entities associated with financing and supporting healthcare activities should provide for the costs of managing healthcare waste.<sup>82</sup> This means that a budget line item for healthcare waste management should always be included in national, local, and facility-level health budgets. The system of pricing can be an incentive or disincentive to minimize waste. For example, a monthly

---

<sup>82</sup> "Core principles for achieving safe and sustainable management of healthcare waste," World Health Organization, Geneva, Switzerland, October 2007.

fee regardless of the quantity of waste is a disincentive to reduce waste, while pricing on a per kilogram basis encourages health facilities to minimize waste.

On the national level, the following are important activities to foster good healthcare waste management in healthcare facilities:

- Legal framework, including designation of responsible authorities and mechanisms for coordination
- Regulations and guidelines, including clearly defined obligations, system of inspection and enforcement, and penalties
- National strategy or plan of action, including support for regional and local governments
- Capacity building measures
- Allocation of human and financial resources.

A good healthcare waste management system requires the effective and environmentally sound **treatment and final disposal of waste**. The technologies described in this Compendium treat sharps and other infectious wastes that comprise the bulk of hazardous healthcare wastes, which in turn accounts for about 15% of total healthcare waste.

As pointed out in the previous sections, an even smaller percentage of total healthcare waste is made up of pharmaceutical, cytotoxic and chemical wastes including mercury as well as radioactive waste. In many countries, the storage, treatment and disposal of these types of waste are covered under regulations dealing with the safe management of chemicals or nuclear waste regulations which are different from regulations pertaining to infectious wastes. Chemical waste treatment technologies include neutralization, chemical oxidation, chemical reduction, wet air oxidation, electrolysis, photolytic reaction, amalgamation, chemical precipitation, encapsulation and stabilization, vitrification, hazardous waste incineration, gasification, plasma pyrolysis, hydrogenation, hydrolysis, a range of biological treatment technologies, and disposal in hazardous waste landfills. These technologies are beyond the scope of this Compendium and are presented in other references.<sup>83</sup>

For a healthcare facility, several practical options exist for small quantities of pharmaceutical waste: return of expired pharmaceuticals to the donor or manufacturer; encapsulation and burial in a sanitary landfill; chemical decomposition in accordance with the manufacturer's recommendations if chemical expertise and materials are available; and dilution in large amounts of water and sewer discharge into a sewer for moderate quantities of relatively mild liquid or semi-liquid pharmaceuticals, such as solutions containing vitamins, cough syrups, intravenous solutions and eye drops.<sup>84</sup>

For cytotoxic waste, treatment options include: return to the original supplier, incineration at 1200°C in specially designed incinerators, and chemical degradation in accordance with the manufacturers' instructions. Chemical degradation methods can be used for drug residues and for cleaning contaminated urinals, spillages and protective clothing but these methods require special knowledge.<sup>85</sup> The UNDP GEF Project has been developing a chemical degradation technology for cytotoxic waste in Argentina.<sup>86</sup>

In general, the management of chemical waste should include with waste minimization. Examples are: substituting with less toxic chemicals, good inventory control, developing spill-prevention and clean-up procedures, and recovering solvents using fractional distillation. Recovery of silver from photo-processing

---

<sup>83</sup> See for example: B. Bilitewski et al., *Waste Management*. Berlin: Springer-Verlag Berlin Heidelberg, 1994; L. Rosengrant and L. Lopez, Treatment Technology Background Document, U.S. Environmental Protection Agency, Washington, DC, 1991; S.E. Manahan, *Hazardous Waste Chemistry, Toxicology and Treatment*, Chelsea, Michigan: Lewis Publishers, 1990.

<sup>84</sup> "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

<sup>85</sup> International Agency for Research on Cancer. Laboratory decontamination and destruction of carcinogens in laboratory waste: some hydrazines. IARC Scientific Publications, No. 54. Lyon, IARC, 1983; International Agency for Research on Cancer. Laboratory decontamination and destruction of carcinogens in laboratory waste: some antineoplastic agents. IARC Scientific Publications, No. 73. Lyon, IARC, 1985.

<sup>86</sup> See [www.gefmedwaste.org](http://www.gefmedwaste.org)

wastewater may be possible using cation exchange, electrolytic recovery or filtration. Some healthcare wastes contain heavy metals, such as mercury from thermometers, sphygmomanometers, cantor tubes, dilators, mercury switches and some button-shaped batteries. A WHO policy paper on mercury in health care outlines a strategy that includes developing safe mercury clean-up, handling and storage procedures; reducing unnecessary use of mercury equipment; replacing mercury-containing products with mercury-free alternatives; and supporting a replacement of the use of mercury-containing devices in the long term.<sup>87</sup> The Secretariat of the Basel Convention has developed technical guidelines on the environmentally sound management of mercury waste.<sup>88</sup>

Radioactive waste account for an even small percentage of healthcare waste and are only found in specialized healthcare facilities. Three disposal methods are possible: “decay in storage”; return to supplier; and long-term storage at an authorized radioactive waste disposal site.

A recent concern among health professionals is the problem of prion waste. Prions are infectious agents made of misfolded proteins which are responsible for transmissible spongiform encephalopathies such as “mad cow disease” and Creutzfeldt–Jakob disease (CJD) in humans. Prions are resistant to heat, radiation, and many disinfectants and are difficult to destroy. However, the high-temperature high-pressure type of alkaline hydrolysis technologies described in this Compendium have been found to be effective under specific conditions of alkaline concentrations, temperature and exposure time.<sup>89</sup>

The use of biological processes to decompose biodegradable healthcare waste is not covered in this Compendium. An example of a biological process is aerobic composting of food waste, garden waste, shredded paper, etc. Vermi-composting is the breakdown of biodegradable material using worms. Anaerobic composting is done in biodigesters to generate gases such as methane which can be used as a fuel source. Some of these technologies have been used for placenta waste as well as general waste in healthcare facilities.<sup>90</sup>

With regards to infectious healthcare waste, there are four approaches to healthcare waste treatment. A decentralized approach is one where the technology is installed on-site at the healthcare facility. By treating the waste as close as possible to the point of generation, this approach has the advantage of eliminating the transport of hazardous healthcare waste.

Another approach is centralized treatment at an off-site facility designed to handle the waste from hospitals, clinics, medical laboratories, doctors’ offices, and other health facilities in a large urban center, province, or region. This approach requires the transport of infectious waste from many sources to the central treatment facility and is only possible if there is a good infrastructure for collection, transport and temporary storage. Its major benefit is cost reduction as it takes advantage of the economies of scale.

A third approach is cluster treatment wherein a hospital serves as a hub for treating waste from surrounding nearby hospitals, clinics, and other facilities. Cluster treatment is an option for small municipalities, parts of a province, or districts that may be too far from a central treatment facility but have an adequate infrastructure for collection and transport of infectious waste within their area.

A fourth approach is mobile treatment. In this approach, the treatment technology is mounted on a mobile platform, such as a specially designed mobile container or a flatbed truck, and is brought to hospitals and other health facilities within a service territory. The mobile treatment system treats and converts infectious waste into regular waste as the mobile unit is parked on the hospital grounds. After treatment, the system is driven to the next healthcare facility.

---

<sup>87</sup> “Mercury in health care,” Policy Paper. Geneva, World Health Organization, 2005.

<sup>88</sup> “Technical guidelines for the environmentally sound management of wastes consisting of elemental mercury and wastes containing or contaminated with mercury,” Secretariat of the Basel Convention, Geneva, Switzerland, 2011.

<sup>89</sup> J. Emmanuel, J. Keene and R. Trower, “Evaluation of Alkaline Hydrolysis Digestion Technology for Decontamination and Disposal of Potentially Infectious Animal Carcasses,” Council Rock Consulting report prepared for the National Institutes of Health, Bethesda, MD, 2005.

---

## 9 PROCESS OF TECHNOLOGY SELECTION

---

This section outlines the general steps for selecting a technology to treat healthcare waste. They are discussed in greater detail in Chapter 13.

**Step 1.** Define the scope of the problem, obtain baseline data, and conduct stakeholder consultations

These activities constitute part of a situational analysis to define the problem and obtain baseline data that serve as a starting point for project analysis as well as a basis of comparison with subsequently acquired data. The baseline data will be helpful in defining the problem in concrete terms during stakeholder consultations with local governments, NGOs and the waste generators. The data should be summarized and presented during stakeholder consultations.

**Step 2.** Conduct a strategic level assessment and determine the desired waste treatment approach: decentralized on-site treatment, cluster treatment or centralized treatment

After compiling the input from stakeholder consultation workshops, a strategic level assessment is conducted by planners, decision-makers, and elected representatives to brainstorm and examine options at the planning and policy level. The most important output from the stakeholder consultations and strategic level assessment is whether a decentralized, cluster or centralized treatment approach should be taken and which healthcare facilities will be covered under the treatment approach.

If the project involves only one facility such as a hospital or clinic, then the approach is likely to be decentralized treatment using one technology installed on-site (in the facility premises). In the case of a very large hospital, several technologies may be preferred to treat the waste within each department of the hospital. The main advantage of decentralized treatment is that all infectious waste is treated before leaving the hospital thereby eliminating the risks associated with transporting infectious materials.

Sometimes a project involves a group of healthcare facilities—such as a chain of hospitals operated by a not-for-profit entity, or all health facilities in a province run by the Ministry of Health or by the provincial government, or a group of separate health facilities that have pooled their resources to treat their waste at a common site, or all the health facilities in a geographical area to be served by a central treatment facility. When a group of facilities are involved, the approach can be decentralized (a treatment technology installed in each facility) or centralized. In most circumstances, centralized treatment, which makes use of the economies of scale, has significant economic advantages.

Cluster treatment is a special case of centralized treatment. A group of health facilities in a small area or district designates a major health facility as its cluster hub. The health facilities in the area transport their waste to the cluster hub to be treated. A typical arrangement is a district hospital serving as a cluster treatment hub for several small hospitals and clinics, private practices, dental facilities, and primary health stations in the district. Each of these treatment approaches are illustrated in Figure 9.1.

---

<sup>90</sup> See Annex 6 in “Safe management of waste from health-care activities,” World Health Organization, Geneva, Switzerland (upcoming edition).

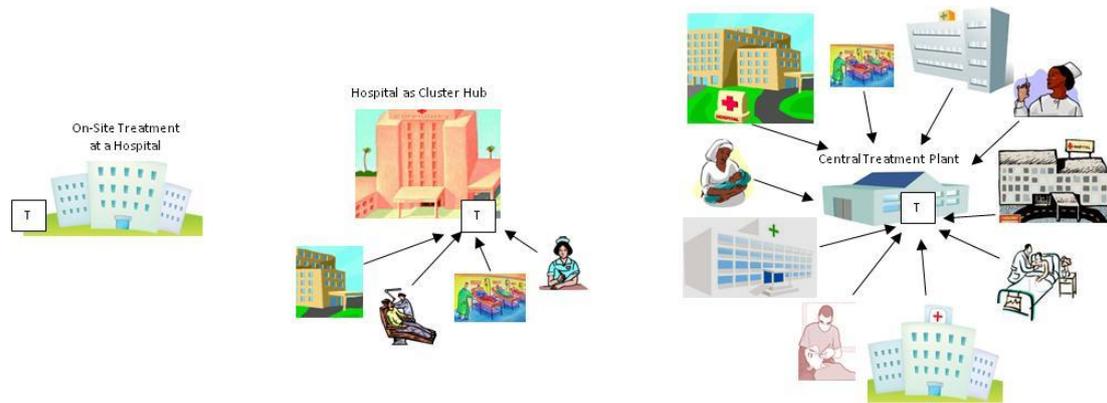


Figure 9.1. L-R: Decentralized, Cluster and Central Treatment Approaches

**Step 3.** Verify facility-specific data or obtain additional facility-specific data by means of a waste assessment or comparison with estimation factors

After the treatment approach has been decided, the next step is to verify facility-specific data or obtain additional data from specific facilities. These include:

- Number of departments and types of services provided
- Percent increase in services expected in the next 10-15 years (for example, a hospital may plan to increase its bed capacity or outpatient services by 25% in the next 10 years)
- Rate of population growth in the area serviced by the health facility/facilities
- Number of beds
- Occupancy rate
- Outpatients per day
- Facility map showing all locations where waste is generated and stored
- Cost of electricity (per kWh)
- Cost of water
- Cost of fuel (diesel, gas, etc.)
- Cost of sewage
- Cost of waste collection and transport of regular (domestic) municipal solid waste
- Cost of land disposal (landfill tipping fees) of municipal solid waste
- Cost of a transport vehicle (for cluster or central treatment)
- Labor rates (for a supervisor, waste handler, and a treatment technology operator)
- The number of 8-hour shifts [shifts/day] and days of the week [operating days/week] that the treatment technology will be operated
- Potential site for installation of a treatment technology
- Total amount of waste generated by the facility or group of facilities to be served by the treatment technology
- Degree of segregation.

To find out how much waste is generated in the facility or group of facilities to be served by the treatment technology, a waste assessment and waste generation data collection should be conducted as described in Chapter 10 unless such an assessment has already been conducted.

A waste assessment is the recommended method to obtain accurate data on waste generation rates for the purpose of specifying equipment capacity. The waste generation rate can be computed using the equations below as appropriate:

$$[\text{Kg/bed-day}] = \text{Total weight of waste [kg] in one day} \div (\text{number of beds})$$

$$[\text{Kg/occupied bed-day}] = \text{Total weight of waste [kg] in one day} \div [\text{number of beds} \times \text{occupancy rate}]$$

$$[\text{Kg/outpatient-day}] = \text{Total weight of waste [kg] in one day} \div (\text{number of outpatients that day})$$

The first two equations are generally used for hospitals while ignoring the number of outpatients or staff; the third equation is used for clinics and primary health posts. Others have proposed a more precise measurement (kg/person-day)<sup>91</sup> wherein “person” combines in-patients, outpatients, and staff, but unfortunately this method has not been widely adopted.

The graphs of waste generation rates presented in Chapter 6 can be used for comparison and to encourage the healthcare staff to do better if waste generation rates are too high. If the hospital is willing to improve its waste segregation practices, the amount of waste to be treated should be adjusted accordingly.

If a waste assessment cannot be conducted in one or more facilities, the estimation factors provided in Chapter 7 may be used. As explained in the next Chapter, bulk densities should also be measured. Again, in the absence of actual measurements, the average bulk density given in Chapter 7 may be used.

Using the waste generation data and average bulk density, the total amount of waste requiring treatment per week should be calculated in terms of kg/week and liters/week. The treatment capacity is then computed using the following equations:

$$\text{Capacity [kg/hr]} = [\text{kg/week}] \div [(\text{shifts/day}) \times (\text{operating days/week}) \times (8)]$$

$$\text{Capacity [liters/day]} = \text{Capacity [kg/hr]} \div [\text{bulk density in kg/liter}]$$

However, when calculating the required capacity, one should consider waste generation rates for the life span of the equipment. Autoclaves, for example, can last 15 to 20 years. Therefore, an estimate should also be made of the waste generation rate 10, 15 or 20 years after the installation. The healthcare facilities may be able to provide estimates of the annual percent growth of their services or they may have specific long-term plans to increase their bed capacity and/or the number of outpatients by a certain percent in a given period. If so, the capacities should be increased by these percentages unless the facility plans to increase the number of shifts or operating hours of the equipment to make up for increasing waste generation. If the facility cannot provide these estimates, one should consider the annual population growth rate of the area served by the facility.

Assessing the level of segregation is essential during the waste assessment. Health facilities that do not segregate properly end up generating more quantities of infectious hazardous waste than necessary thereby requiring larger treatment systems, consuming more energy and other resources, and spending more money than needed. Thus, the selection of a treatment technology should be part of a broader plan of improving the system of healthcare waste management including waste classification and segregation.

**Step 4.** Conduct a screening process to eliminate generic technologies that do not meet the basic criteria

The basic criteria should be based on stakeholder consultations. Examples of basic criteria include compliance with local and national environmental laws. With regards to environment and occupational safety, the recommendations in the WHO policy paper on healthcare waste management, the Basel Convention Technical Guidelines for Environmentally Sound Management of Biomedical and Healthcare Wastes, and the Stockholm Convention Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices should be taken into account.<sup>92</sup> Chapter 11.5 provides qualitative comparisons of generic technologies that could be used to evaluate generic technologies.

---

<sup>91</sup> T.L. Tudor, *Resources, Conservation and Recycling* 50, 319–333 (2007).

<sup>92</sup> “Policy Paper: Safe health-care waste management,” World Health Organization, Geneva, Switzerland, August 2004; Secretariat of the Basel Convention (2003). Technical Guidelines on the Environmentally Sound Management of Biomedical and Healthcare Wastes (Y1; Y3). Châtelaine, Secretariat of the Basel Convention/United Nations Environment Programme; Guidelines on best available techniques and provisional guidance on best environmental practices relevant to  
(footnote continued)

**Step 5.** Conduct a scoping analysis to generate a shorter list of potential technologies

The next step is to decide on preferred aspects or criteria of the desired technology based on the stakeholder consultation workshops and strategic assessments. It may be helpful to conduct the scoping process according to the major topics, such as technical, financial, social and environmental. Participants in the stakeholder group meetings could be selected based on their interests in the particular topic. The following are general considerations for establishing preferences:

- Environment: minimal, some or significant concerns
- Occupational safety: minimal, some or significant concerns
- Job creation (based on equipment size): small, medium or high potential
- Social acceptance: minimal, some or significant concerns
- Capital and operating cost: low, medium or high costs
- Institutional requirements: few, some or many requirements
- Regulatory requirements: few, some or many requirements.

The more in-depth review should focus on the types of waste treated, range of capacities commercially available, the emissions and by-products, operational details, and maintenance requirements. This information is provided in Chapter 11.3. Chapter 11.5 presents additional qualitative comparisons for the following factors: range of capacities, range of waste treated, efficacy of microbial inactivation, volume and mass reduction, space needed for installation, installation requirements, and degree of automation.

**Step 6.** Conduct a detailed technical and economic assessment to come up with a ranking of the top technologies

Step 6 focuses on the five or so technologies that scored the highest or on all the technologies that scored above a cut-off score in Step 5. The shorter list of technologies is subjected to a more detailed assessment using information obtained from the vendor, data from Chapter 12, and other available data.

This approach can be part of a competitive bidding process commonly undertaken for procurement of products and/or services by public agencies. The detailed assessment results in a ranking of the top three or five technologies from which a technology selection is made.

**Step 7.** Review the results, repeat the assessment if necessary, and prepare a written justification for the selection of the top technologies

Before discarding the low-scoring options, review the options for the possibility that appropriate technology transfer, adaptation or capacity building efforts may qualify the technology to be in the top ranks. Explore possible future scenarios and check for changes in the local situation, technical or financial requirements, legislation, or technological developments. Repeat Steps 5 and 6 if deemed necessary due to these changes. Write a justification of the top technology choices and ensure that there is agreement among decision-makers. Provide copies of the justification to participating stakeholders.

**Step 8.** Award the contract.

The contract is generally awarded to the lowest-price bidder or the bidder that best meets the contract award criteria which could include price as well as technical merit and quality.

**Step 9.** Implement the installation and commissioning of the technology.

The bidder fulfills the contract with the shipment, installation, start-up, testing, commissioning and operator training, and the contracting authority completes payment as stated in the contract terms. Sometimes the final payment tranche is made after a regulatory body certifies the technology.

**Step 10.** Monitor and evaluate the performance of the technology.

It is recommended to monitor and evaluate the technology system during its operational phase to ensure that it is meeting the desired objective. The outcomes of the monitoring and evaluation should be reported to the stakeholders, including government agencies, planners and other decision-makers that took part in the selection. This feedback can be helpful for future decision-making.

---

## 10 WASTE GENERATION DATA GATHERING

---

An important initial step in the process of selecting a treatment technology is to know the types and quantities of waste produced in the healthcare facility. Waste generation data from an individual facility are used in estimating the required capacities for containers, storage areas, transport, or treatment technologies. Waste generation data have been used to establish baselines and for procurement specifications, planning, budgeting, calculating revenues from recycling, optimization of waste management systems, and environmental impact assessments.

Healthcare waste generation data are best obtained from a quantitative **healthcare waste assessment**. The assessment entails defining goals, planning, enlisting the cooperation of staff, procurement of equipment, data collection, analysis, and recommendations. The process of waste assessment provides an opportunity to improve current practices, sensitize health workers about waste, and determine the potential for waste minimization. Implementing rigorous segregation during a waste assessment could avoid over-sizing of equipment and result in cost savings.

The design of a waste assessment plan depends on the specific objectives. Generally, data are collected daily by measuring and weighing segregated waste containers from each area of a facility and computing the net weight. Data collection for a period of a few days provides limited information and may not reflect weekly or seasonal variations. Data collection for a month or longer gives a more accurate picture and a better understanding of waste generation but it necessitates a more significant human resources.

The waste assessment plan should be developed in coordination with the healthcare staff. Data from Step 2 in Chapter 9 should be used to determine the best way of conducting the measurements. The actual measurements can be done by a designated person in each department or by a trained waste handler. The waste handler could carry a portable scale and weigh each bag or container as it is removed from the department. The supervisor or designated departmental staff should look at the contents of the bag before they are closed and record the level of fill (waste bags should only be 3/4th full to prevent spillage) and the degree of segregation.

When examining the contents for segregation, the departmental staff can use a pair of tongs or stick to inspect the contents and record the percent of waste that should have been classified as general waste or other type of waste. The contents of infectious or hazardous waste containers or bags should not be removed or transferred. The departmental staff and handler should be adequately protected at all times using personal protective equipment (PPE). PPE, weighing scales, tongs, sticks, and other items that may have come in contact with infectious waste should be washed and decontaminated with 5% sodium hypochlorite solution or other effective disinfectant. Once the bags have been closed, they should not be re-opened.

If the waste cannot be weighed at the point of generation (such as in surgical theaters), the waste bags or containers can be labeled and brought to a central location, such as the storage area, where they can be weighed later. The records for each day should include the occupancy rates and number of outpatients.

In addition to calculating average waste generation rates, information regarding the spread of the data (data range or standard deviation) is important. Other essential parameters are bulk density and a qualitative evaluation of the degree of segregation. An example of a data collection form is given in Table 10.1.<sup>93</sup> Instructions to data collectors should include worker safety, such as using personal protection equipment and avoiding physical contact with infectious items.

---

<sup>93</sup> J. Emmanuel, "Guidance on Conducting a Baseline Assessment of the Model Healthcare Facility," GEF Global Project on Healthcare Waste, United Nations Development Programme, April 2010.



### III. GENERIC TECHNOLOGIES

---

#### 11 TREATMENT TECHNOLOGIES FOR HEALTHCARE WASTE

---

##### 11.1 OVERVIEW

Treatment is near the bottom of the waste management hierarchy. At the top of the hierarchy are the most desirable and preferred approaches, namely, preventing waste in the first place, reducing waste at the source, and reusing materials or recycling when safe to do so. Reducing the amount of bio-hazardous waste at the source entails rigorous segregation. After all approaches to waste minimization have been used, the remaining waste requires treatment and safe disposal of residues, which are at the bottom of the waste management hierarchy.

The goal of treatment is to reduce the potential hazard from healthcare waste thereby protecting public health and the environment. The traditional method of treatment has been incineration which transforms healthcare waste into ash. However, a significant portion of the waste is also transformed into toxic air pollutants which must be captured and the ash itself has to be treated as hazardous waste. Newer technologies transform infectious waste into disinfected or sterile waste that is cleaner than regular domestic waste from a biological standpoint. Some of these technologies allow the recovery of materials that can then be shredded or crushed and recycled. Other technologies speed up the natural decomposition of organic waste. This chapter describes the major types of treatment technologies used for healthcare waste.

##### 11.2 TYPES OF TREATMENT TECHNOLOGIES<sup>94</sup>

There are four basic processes for the treatment of the hazardous components in healthcare waste. These are:

- Thermal
- Chemical
- Irradiative
- Biological.

A fifth process—mechanical—is used as a supplement to the four main processes used in the treatment of healthcare waste.

##### 11.2.1 THERMAL PROCESSES

Thermal processes utilize heat (thermal energy) to destroy pathogens in the waste. This process is used in the majority of treatment facilities around the world. This category can be further subdivided into low-heat and high-heat processes depending on the temperature used. There are marked differences in the thermo-chemical reactions and physical changes taking place in the wastes during their treatment, as well as emissions characteristics, between low-heat and high-heat processes.

Low-heat thermal processes use thermal energy at temperatures high enough to destroy microorganisms but not sufficient to cause combustion or pyrolysis of the waste. Low-heat thermal technologies operate between 100°C and 180°C. The low-heat processes take place in either moist or dry heat environments. Moist (or wet) thermal treatment involves the use of steam to disinfect waste. The technologies utilizing this process are **autoclaves** designed specifically for waste treatment, **hybrid autoclave systems**, and **continuous steam treatment systems**.

---

<sup>94</sup> J. Emmanuel, *Non-Incineration Medical Waste Treatment Technologies*, Health Care Without Harm, Washington, DC, August 2001; J. Emmanuel, C. Hrdinka, P. Gluszynski, R. Ryder, M. McKeon, R. Burkemaier, and A. Gauthier, *Non-Incineration Medical Waste Treatment Technologies in Europe*, Health Care Without Harm Europe, Prague, Czech Republic, June 2004; “Safe management of waste from health-care activities,” World Health Organization, Geneva, Switzerland (upcoming edition).

A technology that is essentially a moist low-heat thermal process is microwave treatment. In microwave systems, disinfection occurs through the action of moist heat (hot water and steam generated by the microwave energy). Microwave units operate at a microwave frequency of 2450 MHz. **Batch microwave technologies** are generally small units, while **continuous microwave technologies** are on a large scale. A technology somewhat similar to microwave treatment is ETD or electro-thermal deactivation. ETD employs low frequency radio waves at 64 MHz to generate a high strength electrical field which causes medical waste to heat up thereby destroying pathogens. Since ETD is not sold as a commercial technology but is a proprietary system used by a service provider (Stericycle), it is not included in this Compendium.

Steam-based technologies such as autoclaves that do not include post-treatment size reduction and microwave technologies that do not incorporate shredding achieve minimal volume reduction (basically only the removal of air, melting of some plastics and collapse of plastic waste bags). For hybrid autoclaves, continuous steam treatment systems, and microwave units that incorporate internal shredding or mixing, volume reductions of 60 to 80% can be achieved depending on the type of shredding used. The steam-based technologies that include a drying cycle can also reduce mass by 15-20%.

A **frictional heat treatment system** uses both moist heat and dry heat thermal processes. The frictional heating system uses a high speed shredder to generate heat, converting moisture in the waste into steam. After all the fluids have evaporated, the waste is further heated to above 135°C up to 150°C for several minutes. These technologies achieve a high volume reduction of about 80% and a mass reduction of 25-30%.

**Dry heat technologies** use hot air, with no addition of water or steam, and operate below combustion temperatures. In dry heat systems, the waste is heated by conduction, convection, and/or thermal radiation using infrared or resistance heaters. Another technology uses frictional heating as the source of heat. As of this writing, commercial dry heat technologies are small-scale units. One dry heat technology does not reduce volume but another can achieve 75-80% reduction.

High-heat thermal processes begin to take place around 180°C and higher, temperatures that result in chemical and physical changes in the waste through combustion, pyrolysis, or gasification. Most high heat thermal processes operate at temperatures above 850°C. **Incineration** is a high-temperature combustion process that reduces organic and combustible waste to inorganic, incombustible solid residues and gaseous combustion by-products. Pyrolysis is the thermal degradation of materials through the application of heat in the absence of oxygen. In actual practice, it is difficult to have a completely oxygen-free atmosphere so some oxidation takes place. Gasification involves the addition of small, controlled amounts of oxygen or steam. Well designed and operated incinerators can reduce volume by 80-90% and mass by about 75%.

### 11.2.2 CHEMICAL PROCESSES

Chemical treatment processes use chemical disinfectants to destroy pathogens in the waste. The microbial inactivation efficacy depends on the type of chemical disinfectant, its concentration, the ability to expose all surfaces, and contact time, but can also be affected by, among others, temperature, pH, water hardness, and amount of organic load in the waste. The most common technologies are **chlorine-based chemical treatment systems** using either dissolved chlorine dioxide or sodium hypochlorite (bleach). Other technologies are **glutaraldehyde/quarternary ammonium compound-based treatment** and **lime slurry or calcium oxide treatment**. More recently, **ozone gas treatment** has also been developed. Past technologies have used peroxyacetic acid, iodophors, and formaldehyde but these disinfectants are no longer used as of this writing. Some small-scale chemical treatment processes also include encapsulating or solidifying compounds that can solidify sharps, blood or other body fluids within a solid matrix prior to disposal. A special case of a chemical process is the **alkaline hydrolysis system** that uses heated alkali to digest tissues, pathological waste, anatomical parts or contaminated animal carcasses in heated stainless steel tanks. Volume reduction depends on the type of shredding, grinding or mixing used by the system.

### 11.2.3 IRRADIATIVE PROCESSES

Some types of radiation have been shown to destroy pathogens. Since ionizing radiation using electron beams and Cobalt-60 are used for sterilization of medical instruments, the concept has been tested for healthcare waste. In the 1990s, electron beam treatment was successfully demonstrated for healthcare waste treatment. Microbial inactivation efficacy depends on the dose absorbed by the mass of waste. UV-C (germicidal UV) irradiation has also been used but as a supplementary technology for healthcare waste treatment. As of this writing, however, there are no commercial healthcare waste treatment technologies using irradiative processes.

### 11.2.4 BIOLOGICAL PROCESSES

Biological processes refer specifically to the natural degradation of organic matter. Some biological treatment systems employ enzymes to speed up the destruction of organic waste containing pathogens. Composting and vermiculture are biological processes and have been used successfully to decompose hospital kitchen waste, as well as other organic digestible waste (Mathur et al. 2006) and placenta waste. The natural decomposition of pathological waste through burial is another example of a biological process. There are no commercially available technologies as of this writing.

### 11.2.5 MECHANICAL PROCESSES

Mechanical processes encompass shredding, grinding, mixing, and compaction. In general, these processes are used to supplement the abovementioned technologies for the purpose of improving the rate of heat transfer, the penetration of steam, or contact with a chemical disinfectant. Mechanical processes are also used to reduce the volume of treated waste, render treated waste unrecognizable, or remove physical hazards in the case of treated sharps waste.

Unless shredders, mixers and other mechanical devices are an integral part of a closed treatment system, they should not be used before the incoming healthcare waste is disinfected. Otherwise, workers are at risk of being exposed to pathogens in aerosols released to the environment by mechanical destruction of untreated waste. If mechanical processes are part of a closed 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 work space or outside environment.

#### **Microbial Inactivation<sup>95</sup>**

When evaluating waste treatment technologies for healthcare waste, the ability to destroy pathogens (disease-causing microorganisms) is a key factor. Microbial inactivation efficacy refers to the capability of a treatment technology for eliminating or substantially decreasing the potential of infectious waste to transmit disease. The terms disinfection and sterilization are often used when discussing treatment efficacy. Disinfection can be defined as the reduction or removal of disease-causing microorganisms in order to minimize the potential for disease transmission. Sterilization is defined as the destruction of all microbial life. Since the complete destruction of all microorganisms is difficult to establish, sterilization of medical and surgical instruments is generally expressed as a 6 Log<sub>10</sub> reduction (i.e., a 99.9999% reduction) or greater of a specified microorganism that is highly resistant to the treatment process. This corresponds to a one millionth (0.000001) survival probability of the microbial population. A 6 log<sub>10</sub> reduction is also called a Log<sub>10</sub> 6 kill, Log<sub>10</sub> 6 reduction, or simply a Log 6 reduction. A 4 Log<sub>10</sub> reduction is a 99.99% reduction of a ten-thousandth (0.0001) survival probability.

<sup>95</sup> J. Emmanuel and E. Krisiunas, "Guidance on the Microbiological Challenge Testing of Healthcare Waste Treatment Autoclaves," UNDP GEF Project on Global Healthcare Waste, November 4, 2010.

The State and Territorial Association on Alternate Treatment Technologies (STAATT) classification system ([www.istaatt.org](http://www.istaatt.org)), in lieu of the terms disinfection or sterilization, denotes levels of "microbial inactivation" specifically for healthcare waste treatment. It was established in order to define measures of performance of healthcare waste treatment technologies. The international microbial inactivation standard for healthcare waste treatment based on the STAATT criteria is Level III, that is: inactivation of vegetative bacteria, fungi, lipophilic/hydrophilic viruses, parasites, and mycobacteria at a 6 Log<sub>10</sub> reduction or greater; and inactivation of *G. stearothermophilus* spores and *B. atrophaeus* spores at a 4 Log<sub>10</sub> reduction or greater.

The representative microbiological indicators generally used to test compliance with this standard are: *Mycobacterium phlei* or *Mycobacterium bovis* (BCG) at a 6 Log<sub>10</sub> reduction or greater; and heat-resistant spores *Geobacillus stearothermophilus* or *Bacillus atrophaeus* at a 4 Log<sub>10</sub> reduction or greater.

Spores of *Geobacillus stearothermophilus*, formerly called *Bacillus stearothermophilus*, are dormant nonpathogenic endospores that are able to withstand the high temperatures of steam treatment as well as dry heat. Spores of *Bacillus atrophaeus*, formerly *Bacillus subtilis* var. *niger*, are also resistant to moist and dry heat as well as chemical inactivation. These bacterial spores more resistant to heat and chemical disinfectants than viruses, vegetative bacteria, fungi, parasites, and mycobacteria. Due to the high resistance of the bacterial spores, validation testing with the spores of *Geobacillus stearothermophilus* or *Bacillus atrophaeus* is generally all that is required for waste treatment autoclaves.

### Sample Test Protocol<sup>96</sup>

Tests should be conducted using waste typical for the particular healthcare facility. Special attention should be given to sharps and lab culture wastes. Test should be conducted using the same containers or bags used by the healthcare facility and sealed as commonly done at the facility. The placement of the sample waste bag in the treatment system should reflect typical placement and stacking arrangements used. If multiple bags are treated, the biological indicators should be placed in the waste bags where treatment is most difficult.

The test should be conducted by personnel specifically trained for this purpose. The test could be done by an autoclave operator if he or she is properly trained and supervised by a facility manager. Occupational safety procedures should be followed when testing infectious waste. The following PPE should be used when opening medical waste bags, placing carriers into the bags, closing bags, and placing bags into the autoclave: heavy duty gloves, face mask, goggles (or face shield), hard sole shoes (or boots), and apron (or protective gown) over regular clothes. The following PPE should be used when retrieving the carriers: heavy duty gloves, hard sole shoes (or boots), apron (or protective gown) over regular clothes, and face shield to protect from steam as needed. PPE should be cleaned after use.

The following are recommended specifications for self-contained biological indicators (SCBIs): Biological indicator: *Geobacillus stearothermophilus* spores; Concentration: > 1 x 10<sup>4</sup> cfu/ml; D-value: greater than 1.5 minutes at 121°C (D-value > 2 min is suggested if available).

If the treatment system treats multiple bags or containers per load, three SCBIs and one control should be used for a challenge test. Each SCBI should be marked to distinguish the test indicators and the control. The three SCBIs should be placed in three separate bags, one of which should be at the center bottom of the stack. If only one bag is treated per load, one SCBI and one control should be used for a challenge test.

Carriers should be prepared to allow easy placement and retrieval of SCBIs. A wooden rod with the SCBI attached by tape at one end, a metal pipe with holes and screwed caps to protect the SCBI, an open ceramic cup tied to a string, a partially cut tennis ball with holes, or stockings are practical examples of carriers used to insert SCBIs into the waste and pull them out afterwards.

Using the autoclave as an example, the following test procedure for placement, retrieval and incubation is recommended:

<sup>96</sup> *Ibid.*

A) Three individual bags typical of the average size of healthcare waste bags in the load are randomly selected. The bags are opened carefully and a carrier placed inside, positioned such that the SCBI is in the middle of the bag. The bags are then fastened in the manner in which they were originally found.

B) The three bags are placed in the center bottom, middle, and top of the batch of waste in the autoclave. The control is set aside and kept at room temperature.

C) After the autoclave is filled in the usual manner, the treatment process is started.

D) The following data should be recorded: name of person conducting the test, date, operating parameters including start and finish times, general description of the waste, and weight of the bag.

E) At the end of the treatment process as the waste bags are removed, the three bags with the carriers are separated.

F) The SCBIs are retrieved from the carriers and observations made to determine if any damage to the SCBIs has occurred.

G) Once observations have been recorded, the three SCBIs and the control are incubated following the instructions provided by the SCBI vendor (typically 24 hours at 55-60°C). The incubator should be able to maintain the temperature within  $\pm 2^\circ\text{C}$  during the incubation period.

H) After incubation, the SCBI ampoules or vials shall be examined for Growth or No Growth following the instructions provided by the SCBI vendor. The results are recorded.

Except for the initial validation test of a new autoclave, the normal frequency of microbiological challenge testing is once a week. If all test indicators show No Growth for four consecutive tests (one month), the frequency of testing can be decreased to once every two weeks. Failures SCBIs that show any damage that may affect the determination of microbial inactivation (such as cracked vials and exposure of spore strips, leaking glass ampoules containing the growth medium, broken caps) should be noted in the report but not included in the determination. There should be three undamaged SCBIs for a test to be valid, otherwise the test should be repeated.

The process is considered successful if all SCBIs show No Growth. If one or more SCBIs indicate Growth, troubleshooting should be conducted to determine the source of the problem, such as the need for equipment maintenance or adjustment of operating parameters (increasing exposure time, temperature, or the number or depth of the vacuum cycles if a vacuum autoclave is used). The test should be repeated for every run until all SCBIs show No Growth. The test should be continued until three consecutive tests show No Growth for all SCBIs. Subsequently, the tests should be conducted weekly until four consecutive tests show No Growth, after which the frequency of testing can be decreased to once every two weeks.

The records of the results of microbiological challenge testing should be made available to regulatory authorities upon request or submitted periodically to regulatory authorities according to existing rules. The records should be kept by the facility for at least three years.

This protocol can be modified to apply to microwave units and steam-based hybrid systems that incorporate internal shredding or mixing such that waste bags are ruptured and the contents released inside the autoclave or microwave chamber. To prevent the SCBIs from being destroyed by internal shredders, the biological indicators would have to be introduced into the unit in a way that would bypass the shredding section. For units that use a mixing arm or paddle or for autoclaves that rotate, a carrier should be design with the following characteristics: relatively small, easy to open and to secure, robust enough to protect the SCBI and to be used repeatedly, designed to allow steam to penetrate easily, easily seen (e.g., painted with bright colors) for retrieval.

11.3 DETAILED DESCRIPTION OF GENERIC TREATMENT TECHNOLOGIES<sup>97</sup>

## 11.3.1 AUTOCLAVES

## 11.3.1.1 Process Description

Autoclaves have been used for over a century to sterilize medical instruments and in the last several decades, they have been adapted for the treatment of healthcare waste. An autoclave consists of a metal vessel designed to withstand high pressures, with a sealable door and an arrangement of pipes and valves through which steam is introduced into and removed from the vessel. Some autoclaves are designed with a steam jacket surrounding the vessel and steam is introduced into both the outside jacket and the inside chamber. Heating the outside jacket reduces condensation on the inside chamber wall and allows the use of steam at lower temperatures. An autoclave without a steam jacket, sometimes called a retort, is also commonly used. Since retorts are cheaper to construct, they are used in large-scale applications.

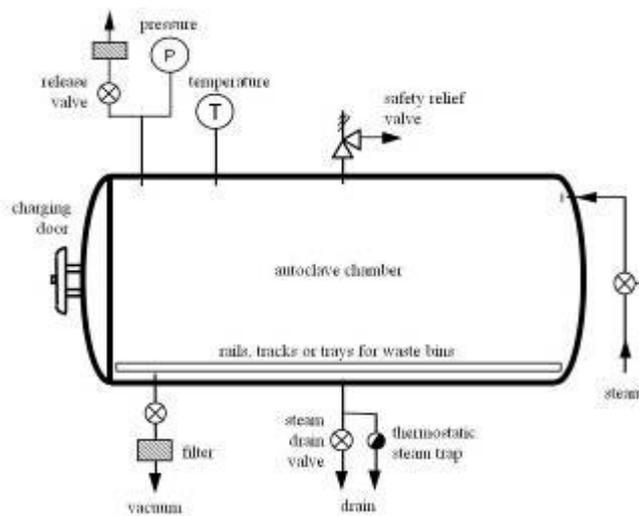


Figure 11.1. Waste Treatment Autoclave

Because air is an effective insulator and a key factor in determining the efficiency of steam treatment, removal of air from the autoclave is essential to ensure penetration of heat into the waste. Unlike instrument sterilization autoclaves, waste treatment autoclaves must treat the air that is removed at the start of the process to prevent the release of pathogenic aerosols. This is usually done by treating the air with steam or passing it through a HEPA filter before being released.

Autoclaves can be subcategorized according to the method of air removal. The three common types are:

- Gravity displacement autoclaves
- Pre-vacuum or high vacuum autoclaves
- Pressure pulse autoclaves.

<sup>97</sup> J. Emmanuel, *Non-Incineration Medical Waste Treatment Technologies*, Health Care Without Harm, Washington, DC, August 2001; J. Emmanuel, C. Hrdinka, P. Gluszynski, R. Ryder, M. McKeon, R. Burkemaier, and A. Gauthier, *Non-Incineration Medical Waste Treatment Technologies in Europe*, Health Care Without Harm Europe, Prague, Czech Republic, June 2004; "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition).

A gravity-displacement autoclave takes advantage of the fact that steam is lighter than air. Hence, steam is introduced under pressure into the chamber forcing the air downward into an outlet port at the bottom of the chamber.

A more effective but costlier method is the use of a vacuum pump and/or a steam ejector to evacuate air before introducing steam, as is done in pre-vacuum (also called high vacuum) autoclaves. Pre-vacuum autoclaves need less time for disinfection due to their greater efficiency in removing air and disinfecting waste.

Other autoclaves use pressure pulsing to evacuate air. The three basic types of pressure pulsing systems are: pressure gravity, vacuum pulsing and pressure-vacuum. Pressure gravity (or steam flushing) entails repeatedly releasing steam and reducing the pressure to near atmospheric after the pressure has reached a pre-determined level and then allowing the pressure to build up again with the addition of steam. Vacuum pulsing is similar to a high vacuum operation except that two or more vacuum cycles are used at the start of the treatment process. Pressure-vacuum systems operate by building pressure then pulling a vacuum and repeating this process several times during treatment. Alternating pressure cycles are used to achieve rapid penetration of steam. In general, the pressure-vacuum systems have the shortest time for achieving high disinfection levels.

Some options provided by autoclave manufacturers include programmable computer controls, tracks and lifts for carts, recording of treatment parameters, weighing scales, autoclavable carts, cart washers, odor-reducing systems, sensors to detect radioactive or chemical wastes, and post-treatment shredders and compactors. 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 tightly stacked containers or carts.

#### *11.3.1.2 Types of Waste Treated*

Autoclaves are capable of treating a wide range of healthcare wastes including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and 'soft' waste (including gauze, bandages, drapes, gowns and bedding) from patient care. With sufficient time and temperature, it is technically possible to treat small quantities of human tissue but ethical, legal, cultural, religious and other considerations may preclude their treatment. Autoclaves are generally not used for large anatomical remains (body parts) since it is difficult to determine beforehand the time and temperature parameters needed.

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

#### *11.3.1.3 Range of Capacities*

Waste treatment autoclave can range in size from about 20 liters to over 20,000 liters per cycle. They operate in a batch mode. Manufacturers' rated capacities range from 1 kg/hour to 2,700 kg/hour including the time needed for putting in the waste, steam exposure, and waste removal.

#### *11.3.1.4 Pathogen Destruction*

Autoclaves have been used for more than a century to sterilize medical equipment. The operation of autoclaves requires the proper combination of temperature/pressure and exposure time to achieve pathogen destruction. In the past, a minimum recommended temperature-exposure time criterion of 121°C for 30 minutes was suggested. However, the effective penetration of steam and moist heat depends on many factors including time, temperature/pressure, process sequence, load size, stacking configuration and packing density, types and

integrity of bags or containers used, physical properties of the materials in the waste (such as bulk density, heat capacity and thermal conductivity), the amount of residual air and the moisture content in the waste.<sup>98</sup> For these reasons, initial challenge tests should be conducted using waste samples that are representative of actual waste produced in a health care facility in order to validate the minimum temperature, pressure and exposure time or pressure pulsing cycle required to achieve the microbial inactivation standard. Test results have shown that medical waste treatment autoclaves can achieve Log<sub>10</sub> reductions of 5, 6 or higher of *Geobacillus stearothermophilus* spores.<sup>99</sup> A report by OnSite Sterilization shows the importance of validation testing to adjust operating parameters in order to ensure that all the waste has been properly treated.<sup>100</sup>

After the initial tests, regular validation tests using biological indicators should be performed at periodic intervals (typically, every week, every 40 hours of use, or once a month, depending on usage). As an added check, strips that contain thermochromic agents that change colour when they reach a given temperature or steam integrators that respond to both time and temperature can be used with each waste load to document that the required temperature has been achieved. Pre-vacuum and vacuum pressure pulse autoclaves also use Bowie-Dick test packs to monitor periodically the air removal system in the autoclave chamber

#### 11.3.1.5 Emissions and By-Products

Since low-heat thermal processes like autoclaving produce significantly less air pollution than high-heat thermal processes, there are no specific pollutant emission limits for autoclaves and other steam treatment systems.

Nevertheless, odors can be a problem around autoclaves if there is insufficient ventilation. If waste streams are not properly segregated to prevent hazardous chemicals from being placed in the treatment chamber, toxic contaminants will be released into the air, condensate or in the treated waste. This happens when waste loads contaminated with laboratory solvents or heavy metals such as mercury are put in the autoclave. Poorly segregated waste may emit low levels of alcohols, phenols, formaldehyde and other organic compounds in the air.

A study at one autoclave facility by the U.S. National Institute for Occupational Safety and Health<sup>101</sup> found no volatile organic compounds in a worker's personal air space and work area that exceeded permissible exposure limits set by the U.S. Occupational Safety and Health Administration. The highest VOC level in the autoclave facility was 2-propanol (isopropyl alcohol or rubbing alcohol), measured at 643 mg/m<sup>3</sup>.

#### 11.3.1.6 Operational Details

As noted earlier, the operation of autoclaves requires the proper combination of temperature/pressure and exposure time to achieve disinfection. In the past, a minimum recommended temperature-exposure time criterion of 121°C for 30 minutes was suggested. Waste loads that are outside the norm, such as bags stacked in a huge pile, waste containing many drapes and blankets, waste with large quantities of liquids such as blood bags,

<sup>98</sup> Lemieux P et al. *Appl. Environ. Microbiol.* 72(2), 7687-7693, 2006.

<sup>99</sup> "Validation Report for a Medical Waste Autoclave," (VariClave VC250 at Gaston Memorial Hospital), OnSite Sterilization LLC, Pottstown, PA, February 20-23, 2010; R. Stringer, J. Kiama, J. Emmanuel, E. Chenya, J. Katima and F. Magoma, "Non-Incineration Medical Waste Treatment Pilot Project at Bagamoyo District Hospital, Tanzania," Joint report by Health Care Without Harm, UNDP GEF Project, AGENDA, John Snow Inc. and Making Medical Injections Safer, September 2010; A. Alvarez, "Steam Sterilization Validation" (test of San-I-Pak autoclave model #353DXL), Northview Pacific Laboratories, Hercules, CA, March 11, 2005; "Validation Report of a WEBECO-Steam Sterilizer for the Treatment of infectious Waste according to DIN 58949 and EN 285," WEBECO, Selmsdorf, Germany, 2005; J. Koogler, "Medical Waste Sterilization Efficacy Testing of Two Bondtech Autoclave Systems," Koogler & Associates Environmental Services report, Gainesville, FL, 1994.

<sup>100</sup> "VariClave: New Insights and Beta Testing," OnSite Sterilization LLC, Pottstown, PA, 2007.

<sup>101</sup> 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." National Institute of Occupational Safety and Health, Cincinnati, OH, November 1997.

very big loads, etc. may require higher temperatures or longer exposure times. Initial challenge tests should be conducted using waste samples that are representative of actual waste produced in the healthcare facility in order to determine or validate the minimum temperature, pressure and exposure time or pulsing cycle required to achieve the microbial inactivation standard.

After the initial tests, regular validation tests using biological indicators should be performed at periodic intervals and color-changing indicators could be used with each waste load to document that the treatment process in addition to time-temperature-pressure logs provided by the equipment.

A typical operation for an autoclave involves the following:

Waste collection: Infectious waste bags are placed in autoclavable cart or bin usually made of stainless steel or aluminum. The cart or bin can be lined with a plastic liner to prevent soft waste from sticking to the sides of the container

Pre-heating (for autoclaves with steam jackets): Steam is introduced into the outside jacket of the autoclave

Waste loading: The cart or bin is loaded into the autoclave chamber. With every load, a color-changing indicator is attached to the outer surface of the waste bag in the middle of the waste load to monitor treatment. The charging door is then closed, sealing the chamber

Air evacuation: Air is removed through gravity displacement, pre-vacuuming or pulse vacuuming

Steam treatment: Steam is introduced into the chamber until the required pressure or temperature is reached. Additional steam is automatically fed into the chamber to maintain the temperature and pressure for a set time period. Pressure pulsing autoclaves vary the pressure according to a set process cycle

Steam discharge: After the treatment cycle is complete, 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 and to dry the waste.

Unloading: Usually, additional time is provided to allow the waste to cool down further, after which the treated waste is removed and the indicator strip is checked. The process is repeated if the color change on the indicator shows that the treatment cycle was insufficient

Documentation: A written log is maintained to record the date, time and operator name; type and approximate amount of waste treated; and post-treatment confirmation results from any automated equipment recording or temperature-pressure monitoring indicator, such as the indicator strip

Mechanical treatment: If desired, the treated waste may be fed into a mechanical process such as a shredder or compactor prior to disposal in a landfill. Treated waste from an autoclave retains its physical appearance. A shredder or grinder is used after treatment to make the waste unrecognizable, if desired. Shredding reduces the volume of the treated waste by 60 to 80 percent, but is prone to break downs. Compactors with high compaction ratios can reduce the volume by as much as 75%.

#### *11.3.1.7 Installation Requirements*

The typical installation requirements are:

- Enclosure and foundation
- Electrical connections
- Water supply
- Drains
- Ventilation

- Steam supply if the autoclave system does not include its own boiler or steam generator
- Water softening system if needed.

Some autoclave systems also require compressed air for pneumatic-based controls. Installation and commissioning can take from a few days to two weeks.

#### *11.3.1.8 Maintenance Requirements*

Maintenance requirements for autoclaves differ according to manufacturers. A detailed maintenance schedule should be provided by the manufacturer during commissioning and as part of operator training. The list below is intended to provide a general idea of the maintenance schedule of a typical waste treatment autoclave.

##### Sample daily maintenance schedule (conducted by the operator)

- (a) Visual checks for steam and water leaks
- (b) Checks for cleanliness of the internal chamber, filter screen for the condensate drain, and door seal; cleaning where necessary
- (c) Inspection of chart recordings for unusual traces and reporting any abnormalities.

##### Sample weekly maintenance schedule (conducted by the operator)

- (a) Checks of operation of the indicator lamps
- (b) Comparison of temperature and pressure gauges with recordings and correlation of temperature and pressure during a cycle
- (c) Inspection of chart recordings for abnormalities.

##### Sample monthly maintenance schedule (conducted by the facility engineer and operator)

- (a) Check of door gasket or O-ring and replacement where necessary following manufacturer's instructions
- (b) Validation test using microbiological indicators to determine microbial inactivation efficacy and adjustment of parameters when necessary (microbiological tests should be conducted more frequently if any test samples fail).

##### Sample quarterly maintenance schedule (conducted by the facility engineer)

- (a) Check of control parameters that may require recalibration or replacement
- (b) Check of valves to determine if they need cleaning or replacement
- (c) Check of piping joints
- (d) Check for corrosion and wear in the chamber
- (e) Inspection of all electrical heat terminal points
- (f) Check for cleanliness of water and steam line main strainers
- (g) Check of piping and drains to ensure they are clear and operating
- (h) Check for correct functioning of door interlocks
- (i) Test of air removal efficiency with the chamber empty.

##### Sample annual maintenance schedule and inspection (conducted by the facility engineer)

- (a) Check of service history for recurring faults and corrective action
- (b) Inspection and removal of any scales from the chamber following manufacturer's instructions
- (c) Check of the water-level control and indicator systems
- (d) Check of condition and operation of temperature indicator and pressure gauges
- (e) Test of the operation of safety valves, door interlocks and other safety and emergency devices under operating conditions
- (f) Check of all control functions including correlation of pressure and temperature against known references, during a cycle with the chamber empty
- (g) Test of all functions under working conditions to the satisfaction of the responsible person

### 11.3.2 HYBRID AUTOCLAVE SYSTEMS

#### 11.3.2.1 Process Description

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, drying the waste, and/or rendering the waste unrecognizable. These systems have sometimes been referred to as advanced autoclaves, hybrid autoclaves or advanced steam treatment technologies. These systems function as autoclaves but combine steam treatment with various kinds of mechanical processes before, during or after steam treatment.

The main types of hybrid autoclaves that are commercially available are:

- Rotating autoclaves or rotoclaves
- Autoclaves with internal shredders
- Autoclaves with internal mixing arms

Each of these systems operates differently. Nevertheless, they treat the same types of waste and have similar emission characteristics as an autoclave.

A rotoclave or rotating autoclave system combines steam treatment with mixing-fragmenting and drying. It was developed by Tempico Manufacturing. The rotating autoclave is designed as a pressure vessel with a rotating internal drum having fixed vanes. As the drum slowly rotates, steam is introduced. The rotation causes waste to tumble against the vanes thereby breaking open bags and containers and allowing the contents of the bags to be exposed to the steam. An optional post-treatment grinder further reduces waste volume down to about 20% of the original volume. Figure 11.2 shows a typical layout of the rotoclave.

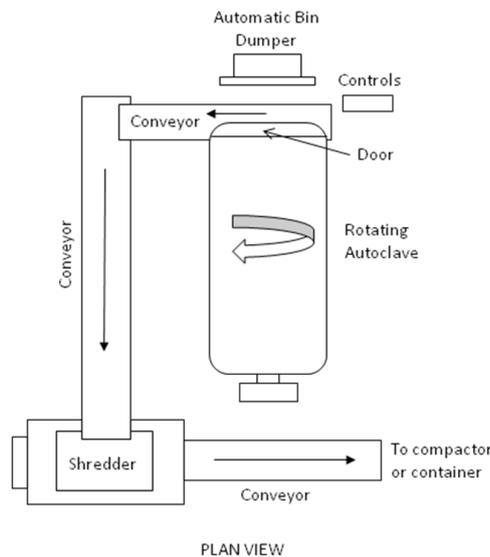


Figure 11.2 Rotating Autoclave (Tempico Rotoclave)

An autoclave with an internal shredder is a pressure vessel containing a rotating impeller or a two-shaft shredder inside the vessel. Generally, after the waste is placed in the vessel and sealed, the waste is first shredded and then steam is injected into the vessel. Figure 11.3 shows a vertical hybrid autoclave by Ecodas, and Figure 11.4 shows a tilting hybrid autoclave by Ecolotec.

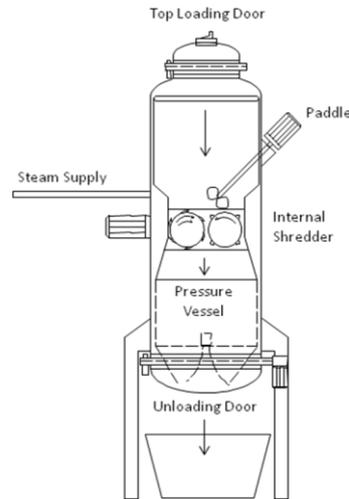


Figure 11.3. Vertical Autoclave With Internal Shredder (Ecodas)

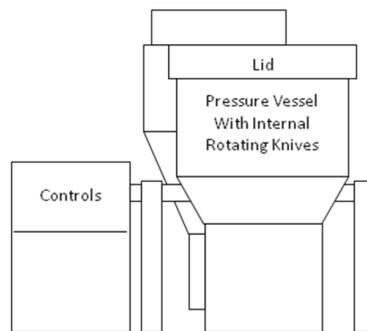


Figure 11.4. Autoclave With Internal Shredder (Ecolotec)

There are also autoclaves that have mixing arms or paddles inside the pressure vessel. The rotating arms or paddles break open the bags and containers allowing the contents to be exposed to steam. Figure 11.5 shows the cross-sectional view of a Hydroclave with a loading lid at the top left, a rotating mixing arm inside the pressure vessel, and steam injected in the outside jacket of the vessel.

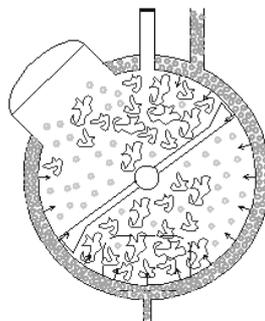


Figure 11.5. Horizontal Pressure Vessel With Fragmenting Arms (Hydroclave)

These hybrid autoclaves have the advantages of being able to achieve high levels of disinfection at shorter times because of the improved rates of heat transfer. They are highly automated and computer controlled and thus, they require very little operator attention. Treatment parameters are automatically recorded thereby

providing the required documentation. Many are designed to remove odors using activated carbon or HEPA filters. Since they involve internal or post-treatment shredding and many have a drying cycle, the resulting waste is not only unrecognizable but also dry and compact, corresponding to as much as 85 to 90% overall volume reduction. One disadvantage with the more sophisticated steam treatment systems is the capital cost, which is higher than for a standard autoclave of the same capacity.

#### *11.3.2.2 Types of Waste Treated*

Hybrid autoclaves are capable of treating the same range of healthcare wastes as autoclaves plus a little more. They can treat cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and 'soft' waste (including gauze, bandages, drapes, gowns and bedding) from patient care. Large and bulky bedding material and sealed heat-resistant containers are easily treated in these hybrid autoclaves.

In addition, some of these hybrid autoclaves, such as the rotating autoclave, have been tested successfully for use with animal waste and pathological waste including anatomical parts. In some countries, legal, cultural, religious, aesthetic, and other considerations may preclude their use.

Volatile and semi-volatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste, and radiological waste should not be treated in hybrid autoclaves.

#### *11.3.2.3 Range of Capacities*

The sizes of hybrid autoclaves range from 38 liters to 21,800 liters. They also operate in a batch mode. Manufacturers' rated capacities range from 18 kg/hour to 3,300 kg/hour.

#### *11.3.2.4 Pathogen Destruction*

Since steam penetration and heat transfer are more efficient in hybrid autoclaves than in standard autoclaves, hybrid autoclaves are able to destroy pathogens easily. In general, they achieve high levels of microbial inactivation as shown by microbiological testing.

Three separate microbial inactivation efficacy tests<sup>102</sup> were conducted on a rotating autoclave (Tempico Rotoclave) 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<sup>103</sup> prepared for Tempico, Log<sub>10</sub> 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.

Microbiological tests of an autoclave with internal shredding (Ecodas) were conducted by the Institut Pasteur de Lille in 1993.<sup>104</sup> A Log<sub>10</sub> reduction of 8 was found for *Staphylococ*, *Mycobacterium smegmatis*, *Aspergillus*

---

<sup>102</sup> Cited in W.L. Turnberg. *Biobazardous Waste: Risk Assessment, Policy and Management*. (New York, NY: John Wiley & Sons, Inc. 1996).

<sup>103</sup> 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.

<sup>104</sup> "Experimentation conducted from November 12 to December 17, 1993," (translated from French), Institut Pasteur de Lille, Lille, France, October 17, 1997.

*niger*, *Bacillus subtilis*, *Enterovirus Polio*, and *Orthopoxvirus* of the vaccine. A subsequent study by the Institute confirmed  $10^6$  reduction of *B. stearothermophilus*.<sup>105</sup>

Test of an autoclave with internal fragmenting arm (Hydroclave) showed inactivation of microbial loads greater than  $10^6$  equivalent of *B. stearothermophilus* within 30 minutes at 121°C or 15 minutes at 132°C.<sup>106</sup> Test conducted on suction canisters, which are difficult to treat, showed a Log10 inactivation of 6 using both *Geobacillus stearothermophilus* and *Bacillus atrophaeus (subtilis)*.<sup>107</sup>

#### 11.3.2.5 Emissions and By-Products

Since low-heat thermal processes like hybrid autoclaves produce significantly less air pollution than high-heat thermal processes, there are no specific pollutant emission limits for hybrid autoclaves and other steam treatment systems.

There may be odors around some hybrid autoclaves but the combination of internal fragmentation of waste and the post-treatment vacuum cycle minimizes the odors. If waste streams are not properly segregated to prevent hazardous chemicals from being placed in the treatment chamber, toxic contaminants will be released into the air, condensate or in the treated waste.

Several tests have been conducted on Hydroclave emissions. A test of volatile organic compounds from the Hydroclave (autoclave with internal fragmenting arm) at the Kingston General Hospital in Canada was conducted in 1988.<sup>108</sup> Samples were taken from the exhaust duct and unloading door. All organic contaminants in the EPA target list were either below the detection limits or well below occupational exposure limits. The highest concentrations were for isopropanol (rubbing alcohol) at 10 mg/m<sup>3</sup> and ethanol at 6 mg/m<sup>3</sup>. (The U.S. Occupational Safety and Health Administration's permissible exposure limits for isopropanol and ethanol are 980 and 1900 mg/m<sup>3</sup> respectively). Another test of volatile organic compounds was conducted in 2002.<sup>109</sup> Samples were taken from the exhaust vent of a Hydroclave unit. Except for trace levels of acetone and pentane at less than a hundredth and a thousandth of the OSHA permissible occupational exposure limits, respectively, no other organic compounds were found above the detection limits.

Wastewater effluent tests were done at a Hydroclave unit in Vancouver, Canada.<sup>110</sup> Total suspended solids and pH were well within the Canadian regulatory limits. For organic and chlorinated compounds with prescribed regulatory limits or standards, the contaminants were either below detection limits or well below the regulatory limits or standards.

Toxicity characteristic leaching procedure (TCLP) tests following the U.S. EPA methodology were conducted on solid waste residues from the Tempico Rotoclave in 1996. The tests showed that the treated waste residues could be classified as non-hazardous.<sup>111</sup>

---

<sup>105</sup> "A controlled study of Waste Decontamination : ECODAS T1000," (translated from French), Institute Pasteur de Lille, Lille, France, October 21, 2002.

<sup>106</sup> 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.

<sup>107</sup> M. G. Holliday, "Report on the Efficacy of the Grundons Hydroclave Clinical Waste Treatment System at Knowl Hill, Maidenhead in Treating Suction Containers," Microbiology Department, Freeman Hospital, Newcastle upon Tyne, UK, April 2005; "Validation Study on Hydroclave Health Care Waste Sterilisation Unit at Grundon Waste Management using *Bacillus stearothermophilus* Spore Strips," Report IMSL2005/02/001.3A, Industrial Microbiological Services Ltd., UK, April 18, 2005.

<sup>108</sup> T. Beardall, "Preliminary Evaluation of Volatile Organic Compounds Associated with a Hydroclave Cycle at Kingston General Hospital," Phoenix OHC, Inc., November 1998.

<sup>109</sup> "Organic Test Survey Report," report by A. Lanfranco and Associates, Inc., Langley, B.C. (Canada), February 20, 2002.

<sup>110</sup> Hydroclave liquid emission test results provided to the author by the vendor.

<sup>111</sup> 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  
(footnote continued)

### 11.3.2.6 Operational Details

Hybrid autoclaves are generally highly automated. The following are the main operational steps for a rotating autoclave based on the Tempico Rotoclave. In this rotating autoclave, the operator is only needed during the loading and unloading steps. The other steps described below are initiated, monitored and terminated by computer controls.

Loading: Waste bags and boxes are loaded into the drum by the operator. This is generally done using a waste dumper that lifts the waste bin into the drum.

Initial vacuum: A vacuum is applied for a few minutes to remove the air in the drum. The evacuated air is mixed with steam to destroy pathogens and passed through a condenser and filter.

Steam pressurization and sterilization: Steam is added until a set pressure is reached. The rotating drum (pressure chamber) operates at about 147°C for about 30 minutes. The combined effects of the steam and the forces due to rotation cause boxes and bags to break up. The agitation helps eliminate cold spots.

De-pressurization, cool-down, vacuum and drying: After treatment, the steam is removed, passed through a condenser and the condensate is discharged to the sewer while residual air is vented through a carbon filter to remove odors. The chamber is then cooled to dry the waste. A final vacuum dries the waste further.

Process unloading: The pressure is then equalized and an alarm sounds to indicate that the chamber door can now be opened. Decontaminated waste is then automatically unloaded by reversing the rotation and discharging the waste on to a conveyor. An optional grinder reduces the waste volume further.

Documentation: The operating parameters can be stored or printed for documentation.

A typical autoclave with an internal shredder, such as the Ecodas, uses a computer-controlled top-loading, double-walled vertical cylinder. After waste is loaded and the lid closed, waste is fed by a moving paddle into a heavy-duty internal two-shaft shredder. The shredded waste falls into the bottom portion of the vertical vessel where it is then heated by steam to about 138°C and a pressure of 3.8 bars. A treatment level corresponding to an 8 log<sub>10</sub> reduction of bacterial spores can be achieved. Cool water is then passed through the outside wall of the inner chamber to reduce temperature and pressure. After the water is drained, a vacuum removes any residual steam from the waste. The treated waste is then removed through a door at the bottom of the vessel. Ecolotec, another autoclave with an internal shredder, uses a bowl-shaped vessel that can be tilted for loading and unloading. After waste is loaded and the bowl is sealed, cutting blades rotating at about 1700 revolutions per minute shred the waste. The system uses vacuum cycles before and after steam injection.

A typical autoclave with mixing or fragmenting arms is the Hydroclave design. It is a double-walled cylindrical pressure vessel that is mounted horizontally. Depending on the size, the Hydroclave may have one or more loading and unloading door. The vessel is fitted with a motor driven shaft, to which are attached fragmenting or mixing arms that slowly rotate inside the vessel. When steam is introduced in the vessel jacket, it transmits heat rapidly to the fragmented waste, which, in turn, transforms liquids in the waste to steam. The system automatically adds steam inside the vessel if the waste does not have enough liquid content. The typical steps for an autoclave with internal fragmenting arms, based on the Hydroclave, are:

Loading: Waste is loaded through one or more the loading doors which are then closed. Loading is done in various ways: manually for small units, through a hydraulically operated waste bin dumper for medium-size units, or using a combination of conveyors, hoppers and waste bin dumpers for large units.

---

Waterford Compliance Group (Pottstown, PA) and Blue Marsh Laboratory (Douglassville, PA) were provided by the vendor. These studies were commissioned by Tempico.

Heating and Fragmentation: Steam is injected into the outer jacket as the mixing arms rotate to break open the containers and mix the waste against the hot vessel walls. Moisture content in the waste is turned into steam. If the waste load does not have a high moisture level, steam is injected into the chamber until the desired pressure is reached.

Sterilization: The mixing arms continue to rotate and temperature inside the vessel is maintained by adding more steam to the outer jacket as needed.

De-pressurization and De-hydration: While maintaining steam in the outside jacket, the chamber is vented through a condenser and de-pressurized. The mixing arms continue to rotate while heat is added through by the outside jacket resulting in de-hydration of the waste.

Unloading: Steam to the outside jacket is shut off. When the unloading door is opened, the mixing arms rotate in a reverse direction causing the waste fragments to be pushed out of the unloading door and into a conveyor belt or waste container. After the chamber is empty, the system is ready for a new load.

Documentation: The operating parameters can be stored or printed for documentation.

#### *11.3.2.7 Installation Requirements*

The typical installation requirements are:

- Enclosure and foundation
- Electrical connections
- Water supply
- Drains
- Ventilation
- Steam supply if the hybrid autoclave does not include its own boiler or steam generator
- Water softening system if needed.

Some hybrid autoclave systems also require compressed air for pneumatic-based controls. In the case of the hybrid autoclave with internal shredding (Ecodas, for example), installation entails mechanical connections to the machine and accessories, installation water connections, connection of compressed air and exhaust air to a vent, drain to a wastewater tank to lower the temperature of the condensate before releasing it into the sewer system, and connection of the power supply to provide power to the control system which in turn powers the motors, pumps, pneumatic system, sensors, switches and other loads. The machine itself has to be hoisted and placed in a vertical position and various parts have to be re-attached. Finally, the waste dumper and other auxiliary equipment are put in place.

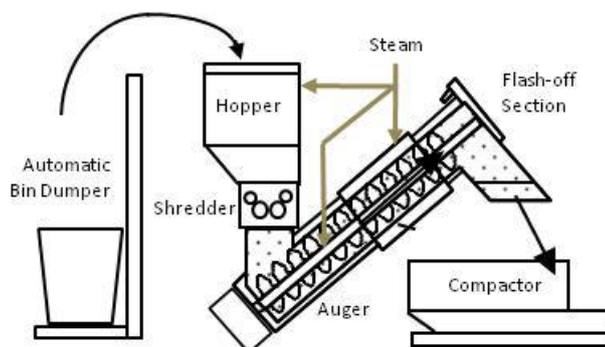
#### *11.3.2.8 Maintenance Requirements*

Hybrid autoclaves generally require more maintenance than standard autoclaves because of the internal moving parts. In addition to the maintenance schedule typical of a standard autoclave, hybrid autoclaves may also require inspection of motors and belts, inspection of bearings and seals, inspection and regular lubrication of sliding surfaces, checking for loose bolts or nuts around gear boxes or hydraulic cylinder mounts, inspection of safety features related to the shredder or mixing arms, and inspection and replacement when needed of worn or broken shredder cutters or mixing arms.

### 11.3.3 CONTINUOUS STEAM TREATMENT SYSTEMS

#### 11.3.3.1 Process Description

Autoclaves and hybrid autoclaves operate as batch processes. There are also integrated steam-based systems that combine internal shredding, steam treatment-mixing and drying in a continuous unit. Their designs are similar to continuous microwave treatment units. Continuous systems are generally composed of a hopper, internal shredder, a slowly rotating screw or auger to convey the waste up an incline, and some method of releasing steam and ejecting the waste into a large bin.



*Figure 11.6. Example of a Continuous Steam Treatment System*

#### 11.3.3.2 Types of Waste Treated

Like hybrid autoclaves, continuous steam treatment systems are capable of treating the same range of healthcare wastes as autoclaves plus more. They can treat cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and ‘soft’ waste (including gauze, bandages, drapes, gowns and bedding) from patient care. Large and bulky bedding material and sealed heat-resistant containers are easily treated in continuous steam treatment systems.

In addition, it is theoretically possible to treat pathological waste including anatomical parts in continuous steam treatment systems with internal shredders. However, legal, cultural, religious, aesthetic, and other considerations may preclude their use.

Volatile and semi-volatile organic compounds, chemotherapeutic waste, mercury, other hazardous chemical waste, and radiological waste should not be treated in steam treatment systems.

#### 11.3.3.3 Range of Capacities

Manufacturers’ rated capacities range from 100 to over 1,000 kg/hour.

#### 11.3.3.4 Pathogen Destruction

Between 1995 and 1997, a series of microbial inactivation tests were conducted on the STI ChemClav by three different laboratories (BBI Clinical Laboratories-Connecticut, ViroMed Laboratories-Minnesota, and Dr. E. Jarroll of Cleveland State University) for various test organisms. Log<sub>10</sub> kills greater than 6 for *B.*

*Stearothermophilus* and greater than 8.5 for *B. subtilis* were reported, as well as log<sub>10</sub> kills greater than 6 for five other microorganisms.<sup>112</sup>

#### 11.3.3.5 Emissions and By-Products

Air quality tests were conducted in 1995 and 1997 by Waterford Compliance Group.<sup>113</sup> All microorganisms found in the exhaust vent of the Chem-Clav were at lower frequencies than the background samples. Samples taken from around the unit showed residual chlorine levels below the detection limit. Independent bio-aerosol field tests were conducted around a large-scale (1000 lbs/hr) medical waste treatment facility and a medium-scale (136 kg/hr) treatment unit at a hospital, both utilizing the continuous treatment system STI ChemClav.<sup>114</sup> The tests of the exhaust discharge from the large-scale system showed microorganism counts less than background samples. At the hospital, microorganism counts from wipe samples at the exhaust vent below the detection limits. Air samples in the waste receiving area and around the unit were below published bio-aerosol concentrations in agricultural workplaces and in ambient air measured in various countries.

Toxicity characteristic leaching procedure (TCLP) tests following the U.S. EPA methodology were conducted on solid waste residues from the ChemClav in 1996.<sup>115</sup> The tests showed that the treated waste residues could be classified as non-hazardous and disposed in a regular landfill.

#### 11.3.3.6 Operational Details

In the case of the ChemClav, waste is loaded 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 an inclined rotating auger (screw) where steam is introduced through multiple ports raising the temperature in the conveyor from 96 to 118°C. The steam is discharged through a vent at the very end of the conveyor and through a condenser causing the waste to dry off. The decontaminated waste exits the conveyor into a self-contained compactor or roll-off container for transport to final disposal. The heavy-duty shredder reduces waste volume down to about 10% of the original.

The operational steps for the LogMed continuous steam treatment system are as follows:

Loading: Before the hopper lid opens, air is extracted from the hopper and passed through a filter to prevent releases of pathogenic aerosols. Waste in a large bin is dumped into the hopper using a hydraulically lifted waste bin dumper.

Internal shredding: After the bin lid is closed, the single-shaft shredder turns on and a hydraulic press pushes the waste into the shredder.

Conveying and heating of solid waste: The shredded waste is then conveyed by a rotating auger up an inclined tube heated by an oil jacket heating system. The temperature of the waste increases to 95°C.

---

<sup>112</sup> S. Trask, "Chem-Clav Microbiological Efficacy Report," BBI Clinical Laboratories, New Britain, CT, July 21, 1997; M.K. Bennett, "STI Chem-Clav Sterilization Asses," ViroMed Laboratories, Minneapolis, MN, December 4, 1995; E. Jarroll, "Evaluation of a Medical Waste Treatment System for Disinfection and Inactivation of *Giardia* Cysts," Cleveland State University, October 2, 1995.

<sup>113</sup> "Air Quality Test Report: Waste Sterilization Equipment Evaluation," Waterford Compliance Group, Pottstown, PA, 1997; "Air Quality Test Report: Waste Sterilization Equipment Evaluation, Residual Chlorine in the Ambient Work Space," Waterford Compliance Group, Pottstown, PA, 1995.

<sup>114</sup> "STI Impact Assessment Report on Bio-aerosol Emissions," Sterile Technology Industries, Inc. (WR2), July 7, 2005.

<sup>115</sup> Analytical tests conducted for the Pottstown Landfill and Recycling Center by Blue Marsh Laboratory, Douglassville, PA, October 14, 1996.

Treatment of excess liquid: Waste with high moisture content will cause liquids to collect in a container under the shredder and the lower part of the auger. The excess liquids are pumped by a filter system to a sterilization container with its own heaters and oil jacket heating system where the liquid is kept at a predetermined time, temperature and pressure. After treatment, the sterilized fluid then goes to a heat exchanger and discharged to the drain.

Additional heating of solid waste: Waste from the first auger is transported to additional rotating screws and continue to be heated through their oil jacket heating systems for a set time to ensure disinfection.

Compression and discharge: As a result of the motion in the screws, the solid waste is compressed as it reaches the discharge section. The shredded, relatively dry, solid waste is discharged through a tube into a waste bin for final disposal.

Documentation: The operating parameters are stored electronically for documentation.

### *11.3.3.7 Installation Requirements*

The typical installation requirements are:

- Enclosure and foundation
- Electrical connections
- Water supply
- Drains
- Ventilation
- ISDN line with modem for remote computer service
- Water softening system if needed.

### *11.3.3.8 Maintenance Requirements*

Continuous steam treatment systems generally require more maintenance than an autoclave because of the internal moving parts. For an 8-hour daily operation, the LogMed technology requires about 2 days of preventive maintenance service every six months, and a 4-day preventive maintenance service every 12 months.

## 11.3.4 BATCH MICROWAVE TECHNOLOGIES

### *11.3.4.1 Process Description*

Microwave treatment is essentially a steam-based process since treatment occurs through the action of moist heat and steam generated by microwave energy. Water contained in the waste is rapidly heated by microwave energy at a frequency of about 2450 MHz and a wavelength of 12.24 cm. In general, microwave treatment systems consist of a treatment area or chamber into which microwave energy is directed from a microwave generator (magnetron).

A typical batch microwave system, as shown in Figure 11.7, is designed to handle between 30 to 100 liters of waste. Some units require reusable, fully enclosed, microwavable containers. The systems may have multiple programmable cycles corresponding to different treatment temperatures or levels of disinfection. A cycle may range from 30 minutes to one hour.

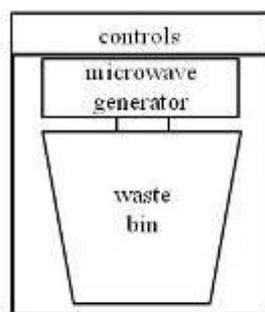


Figure 11.7. Batch Microwave System

#### 11.3.4.2 Types of Waste Treated

The types of waste commonly treated in microwave systems are identical to those treated in autoclaves: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and soft waste (e.g. gauze, bandages, drapes, gowns and bedding) from patient care. Some microwave technologies are not recommended for tightly sealed glass bottles that contain fluid since the pressure inside could cause the bottles to burst. The problem is avoided by leaving glass bottles partially opened. Needles and other sharp metal objects should be in puncture-safe needle containers. Sharps containers should not be hermetically sealed to allow steam penetration.

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

#### 11.3.4.3 Range of Capacities

Manufacturers' rated capacities for batch microwave systems range from 30 to 210 kg/hour.

#### 11.3.4.4 Pathogen Destruction

Studies dating back to the late 1970s showed the efficacy of microwave disinfection for various microorganisms under moist conditions.<sup>116</sup> Technologies, such as the Sintion, have been tested or approved for the sterilization of infectious waste by the Institute of Hygiene at the University of Graz, the Robert Koch Institute (RKI) in Berlin, and the Austrian Society for Hygiene, Microbiology and Preventive Medicine (ÖGHMP).<sup>117</sup> Similarly, the METEKA has been approved by RKI and ÖGHMP. Various laboratories, such as the St. Austell Hospital, Heart Hospital (UK), Sterilizer Consultants Ltd (UK), and London Clinic Pathology Department, have documented the METEKA Medister's microbial inactivation efficacy against *Bacillus atrophaeus*, *Methicillin-resistant Staphylococcus aureus*, *E. coli* infected urine, *Geobacillus stearothermophilus* and other microorganisms.<sup>118</sup>

<sup>116</sup> 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.

<sup>117</sup> "Summary of the Expert-Report: Control of Effectiveness of the Combined Disinfection Procedure Consisting of Micro-waves and Steam, Shown by the Sintion Disinfection Machine," Hygiene-Institut, University of Graz, December 12, 1995; and information provided to the author in 1999 by CMB Maschinenbau and Handels GmbH.

<sup>118</sup> "Medister Approval Certificates – Excerpt," METEKA GmbH, Judenburg, Austria; provided to the author by METEKA in October 2010.

#### *11.3.4.5 Emissions and By-Products*

Air emissions from microwave units are minimal. However, 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.

#### *11.3.4.6 Operational Details*

Microwave batch systems are highly automated. The operation of a typical batch microwave unit is as follows:<sup>119</sup>

Waste loading: The waste bag is placed loosely in the machine and the lid is closed.

Start of operation: The treatment cycle is determined by the type of waste. The operator selects the type of cycle and pushes the start button which automatically locks the lid, seals the chamber and begins the treatment.

Vacuum and steam injection: Depending on the type of waste, the unit uses one or two vacuum cycles. Steam and/or hot water is injected in the chamber.

Microwave treatment: The microwave generator turns on and microwave energy is used to maintain a predetermined temperature and pressure for a set time.

Evacuation: Steam and condensate are drawn out of the chamber, which is flushed with air to cool the waste. Once the pressure equalizes, a signal is sounded to notify the operator of the end of the cycle

Removal of waste: The operator pushes the “open cover” button which unlocks the lid and allows the operator to remove the treated waste.

Documentation: A record of the process is printed for documentation.

Another batch microwave system uses its own wheeled, pedal-operated waste collection system.<sup>120</sup> When full, the container lid is closed and the container is wheeled to the microwave unit and detached from the pedal-operated stand. The container is loaded into the machine, which automatically adds water, heats up the waste using microwave energy, and maintains the waste at the pre-set temperature for 25 minutes before cooling down and allowing the waste to be removed.

#### *11.3.4.7 Installation Requirements*

The batch microwave units have simple installation requirements, typically an electrical connection and water supply.

#### *11.3.4.8 Maintenance Requirements*

For batch microwave units such as the Sintion, maintenance simply involves checking and cleaning filters, checking the seal in the lid, and regular cleaning of surfaces and the interior chamber using household cleaners.

---

<sup>119</sup> Based on the Sintion.

<sup>120</sup> Based on the METEKA Medister.

### 11.3.5 CONTINUOUS MICROWAVE TECHNOLOGIES

#### 11.3.5.1 Process Description

Microwave treatment uses microwave energy at a frequency of about 2450 MHz and a wavelength of 12.24 cm to create steam for disinfection. Continuous microwave units employ 2 to 6 magnetrons with an output of about 1.2 kW each.

A typical semi-continuous microwave system consists of an automatic charging system, hopper, shredder, conveyor screw, steam generator, microwave generators, discharge screw, secondary shredder and controls (see Figure 11.8). The equipment includes hydraulics, high efficiency particulate air (HEPA) filter and microprocessor-based controls protected in an all-weather steel enclosure. Waste bags are introduced into the hopper where steam may also be injected. To prevent release of airborne pathogens, air is extracted through a HEPA filter as the waste bags are loaded. After the hopper lid is closed, waste goes through a shredder. The waste particles are conveyed through a large metal auger (conveyor screw) where they are further exposed to steam and heated to 100°C by four or six microwave generators. Some systems have a holding section to achieve a minimum exposure time. A secondary shredder may be used if treated sharps require finer shredding. A large-scale semi-continuous microwave unit is capable of treating about 250 kg/hour (3000 tonnes per year).

A fully-enclosed microwave unit can be installed in an open area and with a HEPA filter to prevent the release of aerosols during the feed process, odor is somewhat reduced except in the immediate vicinity of the microwave unit.

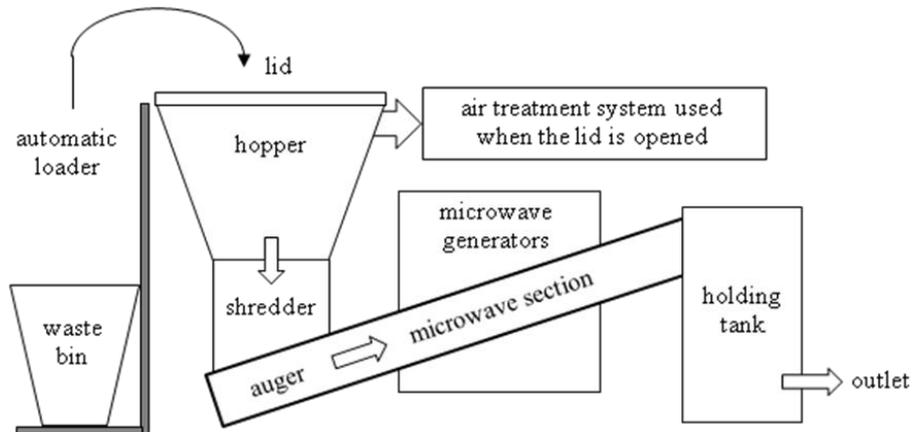


Figure 11.8. Continuous Microwave System

#### 11.3.5.2 Types of Waste Treated

The types of waste commonly treated in microwave systems are identical to those treated in autoclaves: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste (excluding chemical waste) and soft waste (e.g. gauze, bandages, drapes, gowns and bedding) from patient care. Because of the internal shredder and moist heat environment, tightly sealed glass vials and bottles containing fluids, as well as metal objects such as sharps, needles, blades, lancets, etc. can be treated without any difficulty by the continuous microwave technology.

Microwave units with internal shredders, can theoretically be used for pathological waste, just like hybrid autoclaves and continuous steam treatment systems with internal shredders. The Sanitec microwave system has

been successfully tested with animal waste and can be used to treat pathological waste such as tissues.<sup>121</sup> However, legal, cultural, religious, aesthetic, and other considerations may preclude their use.

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

#### 11.3.5.3 Range of Capacities

Manufacturers' rated capacities range from 100 to 250 kg/hour.

#### 11.3.5.4 Pathogen Destruction

A microbiological study on treated waste from a continuous microwave unit (Sanitec) showed no growth of microorganisms (corresponding to a 7 log<sub>10</sub> kill or better) for the following test organisms: *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Nocardia asteroides*, *Candida albicans*, *Aspergillus fumigatus*, *Mycobacterium bovis*, *Mycobacterium fortuitum*, and duck hepatitis.<sup>122</sup> No growth was also shown (greater than 3 log<sub>10</sub> kill) for *Giardia miura*. Tests of the Sanitec prototype in 1988-1989 were used to determine the operating conditions to achieve proper disinfection.<sup>123</sup> The operating parameters were then incorporated in the control system. Other studies show the efficacy of microwave disinfection for other microorganisms under moist conditions.<sup>124</sup>

#### 11.3.5.5 Emissions and By-Products

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 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.<sup>125</sup>

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 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.<sup>126</sup> The highest VOC level in the autoclave facility was 2-propanol, measured at 2318 mg/m<sup>3</sup>. Another study of 11 VOCs (including benzene, carbon tetrachloride, chloroform, and other halogenated hydrocarbons) measured around six

---

<sup>121</sup> Devine A et al., "Testing the Efficacy of a Combination of Microwave and Steam Heat for Log Reduction of the Microbial Load Following a Simulated Poultry Mass Mortality Event." *Applied Biosafety* 12(2), 79-84, 2007; I.F. Salkin and E. Krisiunas, "Treatment of Pathologic Waste by the Sanitec Microwave Disinfection Unit," presented at Fifth International Conference of the Hospital Infection Society (HIS) Meeting, Edinburgh, Scotland, September 15-18, 2002.

<sup>122</sup> "ABB Sanitec Microwave Disinfection System Laboratory Test Results" from North American Laboratory Group and Stanford University, provided to the author in 1996 by Sanitec.

<sup>123</sup> H. Rden, "Hygienic-biological tests of the HG-A-100 S plant for the disinfection of medical wastes (Group C according to the BGA-guidelines)," Expert Opinion, Institute for Hygiene of the Free University of Berlin, Berlin, Germany, January 4, 1990.

<sup>124</sup> 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.

<sup>125</sup> "Evaluation of the ABB Sanitec Microwave Disinfection System for Aerosol Emissions," North American Laboratory Group, New Britain, 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.

<sup>126</sup> 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.

microwave treatment facilities showed that maximum and 8-hour concentrations were either below detection limits or well below permissible exposure limits.<sup>127</sup>

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.<sup>128</sup> Shredding of waste in the microwave unit not only enhances heat transfer but also reduces the volume of waste by as much as 80%. 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.

#### *11.3.5.6 Operational Details*

The operation of a continuous microwave unit is as follows:<sup>129</sup>

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 in about 20 minutes prior to operation. 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.

Documentation: The operating parameters can be printed for documentation.

#### *11.3.5.7 Installation Requirements*

The continuous microwave technology Sanitec comes in its own weather-proof enclosure. It has the following simple installation requirements:

- Foundation
- Electrical connections
- Water supply
- Steam supply unless an optional steam generator is included.

---

<sup>127</sup> "Mixture TLV Results" from Burlington County, JFK Medical Center, Our Lady of Lourdes, West Jersey, Dover General, and Cooper provided to the author by Sanitec.

<sup>128</sup> "Landfill Acceptability of Waste Residue From ABB Sanitec Microwave Disinfection Unit" by Technical Services, Inc. (Jacksonville, FL) provided to the author by Sanitec.

<sup>129</sup> Based on the Sanitec Microwave system.

### 11.3.5.8 Maintenance Requirements

For the continuous microwave unit, the daily maintenance entails an inspection of 24 items including hopper area, filters, steam injection plumbing, microwave generator lamps and fans, hydraulic fluid levels, panel indicator lamps, temperature controllers and chart recorders.<sup>130</sup> This inspection, outlined in a checklist, takes about 15 minutes at the start of the operating shift. Periodic maintenance includes replacement of HEPA filters, inspections of steam lines and valves, cleaning of steam injection points, and shredder maintenance.

## 11.3.6 FRICTIONAL HEAT TREATMENT SYSTEMS

### 11.3.6.1 Process Description

Frictional heat is also used to destroy healthcare waste. The technology utilizes frictional heating supplemented by resistance heaters to heat the waste up to about 150°C while shredding the waste into a dry powder (see Figure 11.9). Heat is provided by heaters and also generated by a high-speed rotor operating at high speeds, typically 1000 to 2000 rpm. The first part of the treatment employs moist heating by steam generated by the rotor causing the waste to reach a temperature of 100°C. The steam and other vapors generated pass through heat exchangers and filters to condense steam and filter the air before being released to the environment. In some designs, it is possible to reuse the condensate. When all the fluids have evaporated, the waste continues to be heated to dry superheated conditions. The waste is kept above 135°C up to 150°C or 151°C for several minutes to achieve sterilization. The whole process takes place at atmospheric pressure. Frictional heating by a high-speed rotor not only pulverizes the waste but causes the rupture of cell membranes, which along with steam heating and dry superheat, results in the destruction of pathogens.

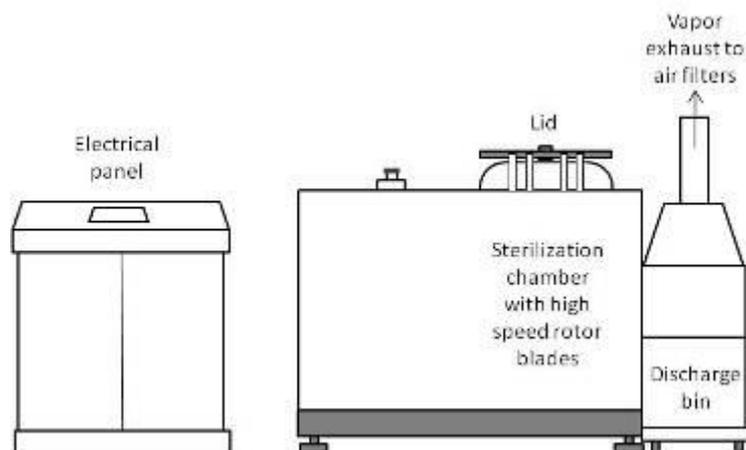


Figure 11.9. Frictional Dry Heat Treatment With Internal Shredding (Newster)

### 11.3.6.2 Types of Waste Treated

The frictional heat treatment systems handle infectious waste that can include cellulose (e.g., gauze and bandages), glass, plastics, metals (needles, lancets and other sharps waste), liquids, and pathological waste (including anatomical parts).

### 11.3.6.3 Range of Capacities

The frictional heat treatment systems range in capacities from 10 to 500 kg per hour.

<sup>130</sup> J. Emmanuel, "Evaluation of the Microwave Medical Waste Treatment System at the University of California-Irvine Medical Center," report prepared for Southern California Edison, CK & Associates, Albany, CA, July 1994.

#### 11.3.6.4 Pathogen Destruction

Microbial inactivation tests of the frictional dry heat technology Newster were conducted by the University of Ferrara.<sup>131</sup> The data showed a Log<sub>10</sub> reduction greater than 6 of *Geobacillus stearothermophilus*. The Ompeco system also documented successful tests using bacterial spores.<sup>132</sup>

#### 11.3.6.5 Emissions and By-Products

Air emission tests were conducted at a hospital operating the Newster system. Metals, inorganic substances, and organic substances were all well below the Italian regulatory limits.<sup>133</sup> Samples of the wastewater from the Newster were also tested.<sup>134</sup> Except for chloride, all parameters and contaminants were below Italian regulatory limits. Samples of the pulverized residue were tested and determined to be non-hazardous.<sup>135</sup> Moreover, a life cycle assessment was conducted by the LCA-lab SRL (Bologna, Italy) of the treatment of healthcare waste using the Newster technology.<sup>136</sup> The study noted decreases in the environmental impacts relative to transportation due to on-site treatment including a reduction in CO<sub>2</sub> emissions compared to transport of untreated waste. Waste from the technology is reduced in mass to 70% of the initial weight and reduced in volume to 35% of the initial volume. The technology reduces the risk to public health and the environment.

#### 11.3.6.6 Operational Details

In the case of a frictional heat treatment system, the typical operational steps as described below involve minimal operator involvement:

Loading: Waste is loaded into the stainless steel vessel, the lid is closed, and the operator pushes a start button to begin the automated cycle.

Initial pulverization: The internal rotor turns slowly to begin shredding the waste.

Frictional heating: The internal rotor turns faster causing the temperature to rise to 100°C. This causes water in the waste to turn to steam. The rotor continues to turn until all the liquid has evaporated and the temperature rises to around 150°C. Small amounts of water could be added to control the temperature. Meanwhile, the vapor goes through condensers and filters.

Cooling: A water spray then cools the waste down to around 95°C after which a short time is allowed to let the steam to condense.

Discharge: A pneumatic system channels the waste into a waste sack. The operator opens the discharge door to remove the shredded, relatively dry waste in the sack. The system is now ready for the next cycle.

---

<sup>131</sup> G. Salvatorelli, "Sterilizing Power of Newster on Medical Residues and Assessment of Environmental Contamination Produced Caused by the System," University of Ferrara, Ferrara, Italy, May 4, 2010.

<sup>132</sup> Tests conducted of the Ompeco system at the hospital of Massa (Tuscany region) Stabilimento Ospedaliero della Fondazione Toscana Gabriele Monasterio Ricerca Medica e di sanità Pubblica, Ospedale del Cuore; tests conducted by the Second University of Naples.

<sup>133</sup> Test report No. 50P, Alfa Laboratorio, Poggiardo, LE, Italy, January 30, 2008.

<sup>134</sup> Test report No. 63P/2008, Alfa Laboratorio, Poggiardo, LE, Italy, January 30, 2008.

<sup>135</sup> Test report No. 59P/2008, Alfa Laboratorio, Poggiardo, LE, Italy, January 30, 2008.

<sup>136</sup> "Environmental impacts deriving from Newster 10 treatment of potentially infectious healthcare waste," Newster Srl, San Giovanni in Marignano, RN, Italy, January 26, 2011.

### 11.3.6.7 Installation Requirements

For the Newster, the installation requirements include:

- Foundation
- Electrical connections
- Water supply
- Drain for wastewater discharge
- Exhaust vent for vapor discharge.

### 11.3.6.8 Maintenance Requirements

For a machine operating 8 hours a day, a typical maintenance schedule is as follows:

#### Sample daily maintenance schedule

- (a) Discharge of remaining water
- (b) Cleaning of the vessel and lid filter
- (c) Checks of the rotor and blades.

#### Sample monthly maintenance schedule

- (a) Cleaning of nozzles, demister, and filters
- (b) Checking of sensors, valves, gaskets, air ducts, and blades, and replacement if necessary.

#### Sample quarterly maintenance schedule

- (a) Checking of blades, fan, belts, and sensors
- (b) Addition of oil
- (c) Cleaning of valves.

#### Sample semi-annual and annual maintenance schedule

- (a) Replacement of filters.

In general, the most frequent equipment parts that need replacement are blades and filter which have a life of about 1.5 years in the case of the Ompeco.

## 11.3.7 DRY HEAT TREATMENT SYSTEMS

### 11.3.7.1 Process Description

Just as circulating hot-air ovens have been used to sterilize glassware, dental instruments, and other reusable medical instruments, the concept of dry heat treatment has been applied to treatment of infectious waste. In dry heat processes, heat is applied without adding steam or water. Instead, the waste is heated by conduction, natural or forced convection or thermal radiation. In forced convection heating, air heated by resistance heaters is circulated around the waste in the chamber (see Figure 11.9). In the past, dry heat technologies have used natural gas or radiant heating by means of infrared or quartz heaters and the heat was conducted through the hot walls of the chamber and/or natural convection.

As a general rule, dry heat processes require higher temperatures and longer exposure times than steam-based processes. They are commonly used to treat small volumes. *Bacillus atrophaeus* spores, which are resistant to dry heat, are used as a microbiological indicator for dry heat technologies.

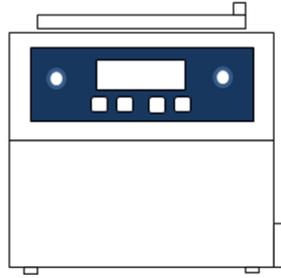


Figure 11.10. Tabletop Dry Heat Treatment Unit (Demolizer)

#### 11.3.7.2 Types of Waste Treated

The small dry heat technology, such as the Demolizer, is intended to treat sharps waste and small amounts of infectious waste as one might find in a clinic, medical or dental office, or in a department of a hospital.

#### 11.3.7.3 Range of Capacities

Dry heat treatment systems are small scale units with capacities in the order of 0.2-0.3 kg/hour.

#### 11.3.7.4 Pathogen Destruction

A series of tests was conducted around the early 1990s on the Demolizer unit. Microbiological tests showed an 8 log<sub>10</sub> kill of *B. subtilis*<sup>137</sup> Tests also showed no growth of *Staphylococcus aureus*, *Candida albicans*, *Mycobacterium fortuitum*, *Mycobacterium bovis*, and *Giardia sp.*<sup>138</sup> Additional tests, all showing no growth, were done by AMA Laboratories using *E. coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*<sup>139</sup> Another test showed inactivation of duck hepatitis B virus by the Demolizer.<sup>140</sup>

#### 11.3.7.5 Emissions and By-Products

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.<sup>141</sup> Results using *B. stearothersophilus* showed no detectable releases of bio-aerosols from the Demolizer to the surroundings.

The treated waste from the Demolizer 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 of treated medical waste by Leberco Testing

---

<sup>137</sup> "Continuous Challenge/Validation Procedure for the Demolizer System" and test results, Leberco Testing, Inc., Roselle Park, NJ, December 9, 1994.

<sup>138</sup> "Efficacy Testing of the Demolizer system medical waste treatment system," Leberco Testing, Inc., Roselle Park, NJ, November 10, 1992.

<sup>139</sup> "Certificate of Analysis," AMA Laboratories, New City, NY, August 25, 1989.

<sup>140</sup> "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.

<sup>141</sup> "Bacterial Emission sample testing from the Demolizer System Medical Waste Treatment System," Valley Medical Laboratory, Springfield, MA, 1998.

(Roselle Park, NJ) for 8 heavy metals showed no metal concentrations above EPA limits.<sup>142</sup> 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.

#### *11.3.7.6 Operational Details*

The operation of a dry heat unit is as follows:<sup>143</sup>

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.

#### *11.3.7.7 Installation Requirements*

For the small tabletop Demolizer, installation only requires a small space and electric power supply. A phone line is used for communication.

#### *11.3.7.8 Maintenance Requirements*

The Demolizer dry heat system has low maintenance requirements.

### 11.3.8 INCINERATORS AND RELATED TECHNOLOGIES<sup>144</sup>

#### *11.3.8.1 Process Description*

Incineration is a high-temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a significant reduction of waste volume and weight. High-heat thermal processes take place at temperatures from about 200°C to over 1000°C. They involve the chemical and

---

<sup>142</sup> "USEPA Regulatory Requirement Levels for Heavy Metal Concentration: Demolizer System Test Results," Leberco Testing, Inc., Roselle Park, NJ, August 2, 1993.

<sup>143</sup> Based on the Demolizer.

<sup>144</sup> Chapter 8 in "Safe management of waste from health-care activities," World Health Organization, Geneva, Switzerland (upcoming edition); B. Bilitewski, G. Härdtle and K. Marek, *Waste Management*, Springer-Verlag Berlin Heidelberg, 1994; C.R. Brunner, *Medical Waste Disposal*, Incinerator Consultants Incorporated, Reston, VA, 1996; C.R. Brunner, *Incineration Systems Handbook*, Incinerator Consultants Incorporated, Reston, VA, 1996; "Operation and Maintenance of Hospital Medical Waste Incinerators," EPA-450/3-89-002, U.S. Environmental Protection Agency, Control Technology Center, Research Triangle Park, NC, March 1989.

physical breakdown of organic material through the processes of combustion, pyrolysis or gasification. A disadvantage of these technologies is the creation of combustion by-products that are released into the atmosphere and the generation of hazardous ash. The combustion of healthcare waste produces gaseous emissions, including steam, carbon dioxide, nitrogen oxides and a range of volatile substances (e.g. metals, halogenic acids, products of incomplete combustion) and particulate matter, plus solid residues in the form of ashes. Appropriate treatment and disposal of bottom ash and residues from flue gas cleaning systems is important.

An incinerator should have a primary combustion chamber (or furnace or kiln), a secondary chamber (or afterburning chamber or post-combustion chamber), air pollution control devices (or flue gas cleaning system or emission controls) to meet national and international standards for pollutant emissions, a wastewater treatment system if a wet system is used for flue gas cleaning, and a stack that is 2.5 times the height of the highest nearby structure. A waste feed system (or charging system) that is able to prevent temperature drops in the primary chamber during feeding of waste, and an ash collection system such as a wet ash sump to prevent dispersion of hazardous incinerator ash are desirable features.

The grate system in the primary combustion chamber is important in promoting combustion of the waste. Old incinerator designs have fixed (or static) grates over an ash pit in the primary chamber, while new designs utilize moving (or traveling) grates, reciprocating grates, or rotating drum grates to allow more efficient combustion. Other incinerators have stepped hearths wherein a series of ash transfer rams on each step push the waste forward towards the end of the hearth and into a discharge chute or water pit. This allows the incinerator to be operated continuously since ash is continuously removed. A more recent design is the vertical stoker in which the combustion zones are configured vertically while supplying pre-heated air from the bottom.

Three generic kinds of incineration design are commonly used for treating healthcare waste: dual-chamber controlled-air incinerators, multiple chamber incinerators, and rotary kilns.

**Dual-chamber controlled-air incinerators** are also known as starved-air incinerators, pyrolytic incinerators, two-stage incinerators or modular combustion units. The controlled-air incinerator is comprised of a primary combustion chamber and a secondary chamber. The waste is thermally decomposed through an oxygen-deficient, medium-temperature combustion process producing solid ashes and gases. The air used for combustion in the primary chamber is less than stoichiometric (that is, the amount of oxygen is less than the ideal proportion needed for burning the carbon and hydrogen). This is often referred to as a starved-air mode or sub-stoichiometric combustion, which decreases turbulence in the primary chamber resulting in less particulate matter pollution. Generally, waste is fed into the primary combustion chamber using a ram feed or feed auger in a manner that keeps the temperature in the primary chamber at or above 850°C. Multiple oil or gas burners maintain the temperature in the primary chamber.

The vapors produced in the primary chamber are directed into a secondary chamber which itself has one or more burners. The secondary chamber is designed to provide excess combustion air, high turbulence, higher temperatures (1100°C for chlorinated wastes such as healthcare waste), and a minimum of 2 seconds residence time (also called retention time) in the secondary chamber. The flue gas (also called the exhaust gas) then goes through the air pollution control system, which may include a gas quenching system, wet or dry scrubber, baghouse filter, venturi-cyclone, electrostatic precipitator, catalytic oxidizer, and various combinations of pollution control devices. After the flue gas is treated, it then goes up a tall stack to be dispersed in the atmosphere. Figure 11.11 shows a schematic of a dual-chamber medical waste incinerator.

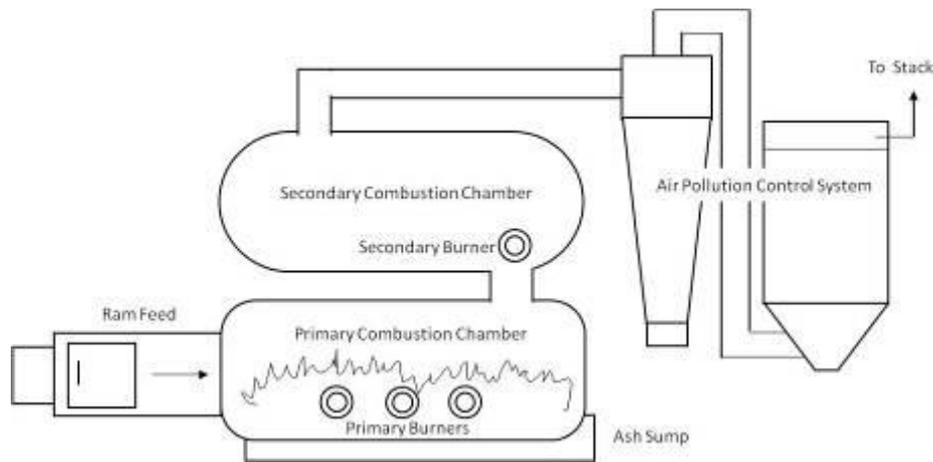


Figure 11.11. Dual-Chamber Controlled-Air Incinerator

Larger pyrolytic incinerators (capacity > 20 tonnes /day) are usually designed to function on a continuous basis. They are also capable of automatic operation, including loading of waste, removal of ashes and internal movement of burning waste.

**Multiple chamber incinerators** were more common in the past and are still used in some countries for pathological waste. These incinerators operate in the excess air mode (above stoichiometric conditions) and require high efficiency air pollution control equipment to meet air pollution limits. There are two major types: in-line incinerators and retort incinerators. In-line incinerators are rectangular in design and have a large primary chamber with a moving grate, a secondary chamber to burn off volatile organic compounds in the flue gas and additional chambers that force the gas to turn in different directions to remove particulate matter as ash residues.

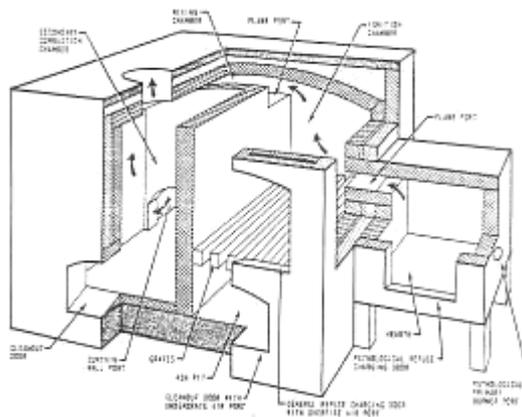


Figure 11.12. Multi-Chamber Excess Air Incinerator<sup>145</sup>

Retort incinerators have a primary and a secondary chamber arranged in a “U” shape. Flue gas from the primary chamber (hearth) is generally passed under the primary chamber to add heat to the hearth. Figure 11.12 is an example of a multiple chamber incinerator for pathological waste. Both types of incinerators use supplemental fuel to reach temperatures of around 800 to 1000 °C. As mentioned, these designs are no longer commonly used because of their high volumes of airborne emissions and are not included in this Compendium.

<sup>145</sup> From J.S. Danielson (editor), *Air Pollution Engineering Manual*, Second Edition, Air Pollution Control District, County of Los Angeles, May 1973.

A **rotary kiln incinerator** has an inclined rotating combustion chamber and a post-combustion secondary chamber. The main characteristics of rotary kilns are: high incineration temperatures in the range 900 to 1200 °C; incinerator capacities up to 10 tonnes per hour; a combination of air pollution control devices to clean the flue gas, and high energy consumption. Well trained personnel are needed to operate the equipment.

The axis of a rotary kiln is inclined at a slight angle to the horizontal (3 to 5% slope). The kiln rotates 2 to 5 times per minute and is charged with waste at its upper end. There are co-current and counter-current rotary kilns; co-current means the flow of solids and flue gas are in the same direction, while in counter-current flow, the flue gas flows in the opposite direction as the waste. Ashes are subsequently discharged at one end. Often an ash sump or container is used to minimize airborne release of incinerator ash. The gases produced in the kiln are heated to high temperatures to burn off gaseous organic compounds in the secondary chamber and typically have a long residence time of 2 or more seconds. The flue gas is cleaned using a combination of different air pollution control devices such as a gas quencher, venturi-scrubber, wet or dry scrubber, addition of adsorbing and neutralizing agents (e.g., activated carbon, lime and limestone solutions), baghouse filter, ceramic filter, venturi-cyclone, electrostatic precipitator, catalytic oxidizer, fabric filter with catalysts, and fixed or fluidized bed towers.

Rotary kilns may operate continuously and are adaptable to a wide range of loading devices including internal ram feeders and feed augers. They are also used to treat hazardous chemical waste under controlled conditions. Those designed to treat toxic wastes should preferably be operated by waste disposal agencies specializing in hazardous waste incineration and monitored by regulatory authorities. As with all large-scale operations, these incinerators should be located in industrial areas away from residences, schools, farms, healthcare facilities, and other highly populated and sensitive areas. Figure 11.13 shows an example of a rotary kiln incinerator.

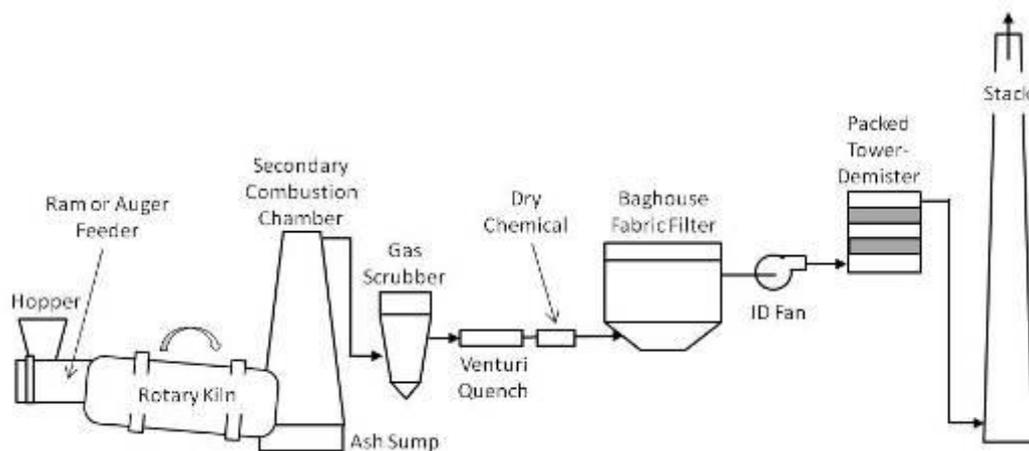


Figure 11.13. Example of a Rotary Kiln Incinerator

### Co-incineration

Co-incineration is the practice of burning or co-processing healthcare waste with other types of waste. Since the Stockholm Convention guidelines recommend against co-incineration or co-processing of infectious waste with other wastes, it is only briefly mentioned here. Examples of co-incineration of infectious waste include hazardous waste incinerators, industrial cement kilns, and steel works. Hazardous waste incinerators use controlled flame combustion mainly in rotary kilns involving temperatures greater than 1,100 °C if the chlorine content is above 1 % (as would be the case for healthcare waste) and a residence time greater than 2 seconds.<sup>146</sup> Cement kilns are used to heat a mixture of limestone and clay or shale to temperatures up to 1450 °C to form cement. Because of the high temperatures needed and the alkaline conditions that can absorb acid gases in the kiln, combustible wastes have been burned along with the fuel used for firing the cement kiln. Waste materials,

<sup>146</sup> "Hazardous Waste Incineration," POPs Technology Specification and Data Sheet, Basel Convention Secretariat (no date).

in particular plastics, have been used as a supplementary fuel in blast furnace iron-making. When combined with coal or coke, the plastics help reduce the iron ore but only a small amount can be used to prevent damaging the furnace. Waste plastics have been used at higher amounts as a source of both energy and carbon in electric arc furnace steelmaking.<sup>147</sup>

Co-incineration is practiced in some industrialized countries with sophisticated technologies capable of controlling feed rate and emissions. Co-processing of healthcare waste in cement kilns and steelmaking requires careful monitoring and control of feed mixtures and emissions. In cement kilns, the optimal conditions to minimize pollutants due to the addition of waste could adversely affect the quality of the cement product. Healthcare waste generates more hydrochloric acid than municipal solid waste so flue gas cleaning systems have to be adjusted accordingly. Co-incineration with healthcare waste requires special procedures and training for transporting, storing, handling and loading the waste in a manner that prevents exposure of workers to infectious agents. In developing countries, this could mean significant additional investments to modify the facilities for safe handling and loading of medical wastes and for flue gas cleaning.

### **Gasification, Plasma Pyrolysis and Related Technologies<sup>148</sup>**

More advanced types of incinerators exist, such as fluidized-bed incineration and incineration with slag and particle vitrification, but these technologies have not been extensively used in healthcare waste. Other high-temperature technologies, such as superheated steam detoxification, induction heat pyrolysis and thermal depolymerization, have been also been tried in industrialized countries.<sup>149</sup> Research has focused particularly on gasification and plasma pyrolysis for healthcare waste applications.

Gasification and pyrolysis processes operate with sub-stoichiometric air levels. Gasification is the conversion of a solid or liquid substance into a gaseous mixture by partial oxidation with the application of heat. Partial oxidation is usually achieved by restricting the level of oxygen (or air) in the combustion chamber (pyrolysis). The process is optimized to generate the maximum amount of gaseous breakdown products, typically carbon monoxide, carbon dioxide, hydrogen, methane, water, nitrogen and small amounts of higher hydrocarbons. Depending on whether oxygen or air is used, the calorific value of the gas is either less than 25% of natural gas, or between 25-40% of natural gas. Gasification still generates solid and liquid by-products, which may contain high levels of toxic contaminants.

Pyrolysis is the thermal degradation of a substance in the absence or with a limited supply of oxygen. However, with healthcare wastes a complete absence of oxygen is impossible. As a result, some oxidation will occur during pyrolysis such that dioxins, furans and other products of incomplete combustion can still be generated.<sup>150</sup> In the case of healthcare waste treatment, plasma pyrolysis refers to the use of a highly ionized gas (plasma) to convert electric energy to heat at temperatures around 1650°C and higher. Some systems use a plasma arc torch creating a high energy electrical discharge or arc between two electrodes. A carrier gas such as argon passes between the electrodes and transfers the energy to the waste material. Another design is a direct current plasma arc wherein the arc forms between a graphite electrode and the metal in a molten bath formed from the waste in the treatment chamber. Other systems use a non-transferred arc wherein the anode and cathode are both part of the plasma torch. Since plasmas generate a high energy electrical discharge, they require significant amounts of electrical energy to operate.

While pyrolysis systems differ in some respects to conventional incineration, they are sufficiently similar to incinerators to be legally classified as such by the European Union. The U.S. Environmental Protection Agency treats gasification as an incineration system. Both technologies require sophisticated process control and efficient

---

<sup>147</sup> V. Sahajwalla, L. Hong and N. Saha-Chaudhury, *Iron & Steel Technology*, pages 91-96, April 2006.

<sup>148</sup> J. Emmanuel, P. Costner and D. Luscombe, "HCWH Update on Pyrolysis – a non-traditional thermal treatment technology" Health Care Without Harm, Washington, DC, 2001.

<sup>149</sup> J. Emmanuel, "New and Emerging Technologies for Medical Waste Treatment," CR-107836-R2, EPRI Healthcare Initiative, Palo Alto, CA, 1999.

<sup>150</sup> Weber, R., Sakurai, T., "Formation characteristics of PCDD and PCDF during pyrolysis processes," *Chemosphere* 45: 1111-1117, 2001; Mohr, K., Nonn Ch. And Jager J., "Behaviour of PCDD/F under pyrolysis conditions," *Chemosphere* 34: 1053-1064, 1997.

pollution control devices. Most are still in the development phase. Since the application of these technologies to healthcare waste are limited in industrial countries, and the capital and operating costs are considerable, they are not included in this Compendium.

#### *11.3.8.2 Types of Waste Treated*

Incinerators can treat a wide range of healthcare wastes including cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery waste, laboratory waste, and 'soft' waste (including gauze, bandages, drapes, gowns and bedding) from patient care. Incinerators specially designed for pathological waste are used to burn cadavers, large anatomical remains (body parts, organs, tissues and animal carcasses). High temperature ( $\geq 1,200^{\circ}\text{C}$ ) incinerators specially designed for hazardous chemical waste and equipped with high-efficiency air pollution control devices are used to treat laboratory chemical waste, thermally stable pharmaceutical waste, halogenated waste including plastic PVC materials, and chemotherapeutic (cytotoxic) waste.

The following materials should not be incinerated: pressurized gas containers; large amounts of reactive chemical waste; silver salts and photographic or radiographic wastes; waste containing mercury, cadmium and other heavy metals, such as broken thermometers, used batteries and lead-lined wooden panels; sealed ampoules or vials that can burst; and radioactive materials.

Incineration of waste is affordable and feasible only if the calorific value of the waste is greater than 2000 kcal/kg (8370 kJ/kg). Although plastics can exceed 4000 kcal/kg (16 740 kJ/kg), some healthcare waste contain a high proportion of moisture and have much lower calorific values. Pathological waste has a low calorific value of about 400-200 kcal/kg (2000-8400 kJ/kg). Additionally, the waste should have a combustible content greater than 60% and a non-combustible portion less than 5%. Ideally, the moisture content should be less than 30%.

#### *11.3.8.3 Range of Capacities*

Incinerators range in capacities from about 10 kg/hour to 100 tonnes a day.

#### *11.3.8.4 Emissions and By-Products*

Healthcare waste incinerators release a wide variety of pollutants depending on the composition of the waste. These pollutants include particulate matter such as fly ash; heavy metals such as arsenic, cadmium, chromium, copper, mercury, manganese, nickel, and lead; acid gases (hydrogen chloride, hydrogen fluoride, sulfur dioxides, nitrogen oxides); carbon monoxide; and organic compounds like benzene, carbon tetrachloride, chlorophenols, trichloroethylene, toluene, xylenes, trichloro-trifluoroethane, polycyclic aromatic hydrocarbons, vinyl chloride, etc. Pathogens can also be found in the solid residues and in the exhaust of poorly designed and badly operated incinerators.<sup>151</sup> In addition, the bottom ash residues are generally contaminated with dioxins, leachable organic compounds, and heavy metals and have to be treated as hazardous waste.

Incinerator emissions should comply with national standards and the Stockholm Convention guidelines for those countries that have ratified or acceded to the convention. If national authorities have not established healthcare waste incinerator regulations, the Stockholm Convention guidelines or international standards as shown in Table 11.1 could be followed.

---

<sup>151</sup> M. Barbeito and M. Shapiro, "Microbiological Safety Evaluation of a Solid and Liquid Pathological Incinerator," *J. Medical Primatology*, 6:264-273, 1977; S. Klafka and M. Tierney, "Pathogen Survival at Hospital/Infectious Waste Incinerators," Proceedings: National Workshops on Hospital Waste Incineration and Hospital Sterilization, EPA Office of Air Quality Planning and Standards, EPA-450/4-89-002, January 1989; Hospital Medical Waste Incinerator Operation and Maintenance, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 1989.

Incinerators generally cannot meet modern emission standards without emission controls. The Stockholm Convention on Persistent Organic Pollutants, a legally binding treaty ratified by over 170 countries, issued guidelines for best available techniques and best environmental practices to limit the levels of dioxins and furans in incinerator emissions to 0.1 ng I-TEQ/Nm<sup>3</sup> at 11% O<sub>2</sub>.<sup>152</sup> Moreover, dioxins in the wastewater of treatment plants treating effluents from any gas treatment scrubber should be well below 0.1 ng I-TEQ per liter. Dioxin concentrations in the flue gas of healthcare waste incinerators could be 93 to 710 times higher than the international standard depending on the waste composition.<sup>153</sup> The Stockholm Convention guidelines list primary and secondary measures to achieve the performance levels for dioxins and furans. The primary measures are:

- Introduction of the waste in the combustion chamber only at temperatures of ≥ 850 °C
- Installation of auxiliary burners for start-up and shut-down operations
- Avoidance of starts and stops of the incineration process
- Avoidance of temperatures below 850°C and cold regions in the flue gas
- Control of oxygen input depending on the heating value and consistency of feed material
- Minimum residence time of 2 seconds above 850°C in the secondary chamber after the last injection of air or at 1100°C for wastes containing more than 1% halogenated organic substances (generally the case for health care waste) and at least 6% O<sub>2</sub> by volume
- High turbulence of exhaust gases and reduction of air excess by injection of secondary air or re-circulated flue gas, pre-heating of the air-streams or regulated air inflow
- On-line monitoring for combustion control (temperature, oxygen content, CO, dust), operation and regulation of the incinerator from a central console.

Table 11.1. Emission Limits for Healthcare Waste Incinerators<sup>154</sup>

Pollutant	Units	Standard conditions <sup>1</sup>	US EPA emission limits			EU emission limits		
			Small <sup>2</sup>	Medium <sup>2</sup>	Large <sup>2</sup>	Daily ave	Half-hour ave <sup>3</sup>	0.5-8 hour ave
Particulate matter or total dust	mg/m <sup>3</sup>	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	66	22	18	10	10, 30	
Carbon monoxide	ppm(v)	273°K, 101.3kPa, 11% O <sub>2</sub> , dry	20	1.8	11	50	100 <sup>4</sup>	
Dioxins/furans	ng TEQ /m <sup>3</sup>	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	0.013	0.014	0.035			0.1 <sup>5</sup>
Gaseous & vaporous organics as total organic carbon	mg/m <sup>3</sup>	273°K, 101.3kPa, 11% O <sub>2</sub> , dry				10	10, 20	
Hydrogen chloride	ppm(v)	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	15	7.7	5.1			
Hydrogen fluoride	mg/m <sup>3</sup>	273°K, 101.3kPa, 11% O <sub>2</sub> , dry				10	10, 60	
Sulfur dioxide	ppm(v)	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	1.4	1.4	8.1	1	2, 4	
Nitrogen oxides	mg/m <sup>3</sup>	273°K, 101.3kPa, 11% O <sub>2</sub> , dry				50	50, 200	
Cadmium	ppm(v)	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	67	67	140	200	200, 400	
Cadmium & thallium	mg/m <sup>3</sup>	273°K, 101.3kPa, 11% O <sub>2</sub> , dry	0.017	0.0098	0.00013			total 0.05
Mercury	mg/m <sup>3</sup>	20°C, 101.3kPa, 7% O <sub>2</sub> , dry	0.014	0.0035	0.0013			0.05
Lead	mg/m <sup>3</sup>	273°K, 101.3kPa, 11% O <sub>2</sub> , dry	0.31	0.018	0.00069			total 0.5
Antimony, arsenic, lead, chromium, cobalt, copper, manganese, nickel, vanadium and their	mg/m <sup>3</sup>	20°C, 101.3kPa, 7% O <sub>2</sub> , dry						
		273°K, 101.3kPa, 11% O <sub>2</sub> , dry						

<sup>152</sup> Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Geneva, Stockholm Convention Secretariat, United Nations Environment Programme, 2006.

<sup>153</sup> Ferraz M et al., “Dioxin emission factors for the incineration of different medical waste types,” *Archives of Environmental Contamination and Toxicology*, 44, 4, 460-6, 2003.

<sup>154</sup> “Standards of Performance for New Stationary Sources and Emissions Guidelines for Existing Sources: Hospital/Medical/Infectious Waste Incinerators – Final rule amendments,” 40 CFR Part 60, US Environmental Protection Agency, 2011; Annex V of the “Directive 2000/76/EC on the incineration of waste,” European Parliament and the Council of the European Union, 2000.

compounds

<sup>1</sup> Different standard conditions are defined for EPA and EU limits; corrections have to be made to convert between different standard temperatures and percent oxygen. <sup>2</sup> EPA defines small incinerators as having a waste burning capacity  $\leq 200$  lbs/hr, medium capacity as  $> 200$  to 500 lbs/hr, and large capacity as  $> 500$  lbs/hr. <sup>3</sup> At least 97% of half-hourly average concentrations must meet the first value and 100% must meet the second value. <sup>4</sup> All half-hourly average concentrations taken in any 25-period must meet this value. <sup>5</sup> The sampling period for dioxins/furans must be a minimum of 6 hours and a maximum of 8 hours under the EU directive.

The secondary measures to further reduce dioxins and furans are an appropriate combination of dust removal equipment and other techniques. The most common types of dust removal equipment used at incinerator plants are cyclones, fabric filters (fabric dust removers or baghouse filters), ceramic filters, cyclonic scrubbers, and electrostatic precipitators. Flue gas from the post-combustion chamber is at about 800 to 1000°C and must be cooled rapidly to 200 or 250°C to prevent synthesis of dioxins and furans in the post-combustion zones. This can be achieved in quenchers (cooling towers or quenching towers or baths). Many incinerators use a heat recovery boiler to generate steam, hot water, or electricity.

Acid gases such as hydrochloric acid (HCl), hydrofluoric acid (HF), and sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) also have to be removed from the flue gas. Three processes are used: wet, semi-dry and dry. In the wet process, gases are washed in a spraying tower with soda or lime solution, which also contributes to gas cooling and to the removal of very small particulates. In the semi-dry process (also known as semi-wet process), a lime suspension is injected into the gas column. Salts generated by the neutralization process have to be removed. In the dry process, lime powder is injected into the gas column and the salts produced during the neutralization have to be removed. The wet process is the most efficient but it requires complex treatment of the wastewater which must be neutralized before being discharged into a sewer. Sludge from wastewater treatment and from cooling of fly ash should be considered as hazardous waste and can be sent to a waste disposal facility for hazardous chemicals or treated on-site by drying followed by encapsulation. Other secondary measures listed by the Stockholm Convention guidelines to reduce dioxins include catalytic oxidation, fabric filters coated with catalyst, fixed bed reactors and adsorption using activated carbon.

In the past, ash residues (also known as bottom ash) from healthcare waste incineration were assumed to be less hazardous than fly ash. UNEP tested hospital waste incinerators that had been built in the mid 1990s and reported that the bottom ashes from a hospital waste incinerator had extremely high dioxin/furan levels, between 1410 and 2300 ng I-TEQ/kg.<sup>155</sup> The reasons for extremely high concentrations in the bottom ashes reflect the inefficient combustion in the furnace and the synthesis of PCDD/PCDF overnight. Growing concern about potential leakage of toxic substances from the ashes has led some countries to require that the ashes be disposed of in landfills designed specifically for hazardous substances.

Under the Stockholm Convention's BAT/BEP guidelines, the appropriate treatment and disposal of incinerator ash include disposal in safe landfills, catalytic treatment of filter dusts under conditions of low temperature and low oxygen, scrubbing of filter dusts to extract heavy metals, vitrification or other immobilization methods (such as cement solidification) of filter dusts followed by landfilling, or plasma treatment of incinerator ash.<sup>156</sup>

Carbon monoxide, oxygen in the flue gas, particulate matter, hydrogen chloride, sulfur dioxide, nitrogen oxides, hydrogen fluoride, airflows and temperatures, pressure drops and pH in the flue gas should be routinely monitored according to national laws and regulations.

#### *11.3.8.5 Operational Details*

The general operational procedures for a healthcare waste incinerator are as follows:

<sup>155</sup> "Thailand Dioxin Sampling and Analysis Program – Report," United Nations Environment Programme, 2001; <http://www.chem.unep.ch/pops/pdf/thdioxsamprog.pdf>

<sup>156</sup> Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Geneva, Stockholm Convention Secretariat, United Nations Environment Programme, 2006.

Waste charging: Waste is introduced into the primary chamber ideally using a ram feeder, feed auger or other automated charging system that is computer controlled such that the primary chamber temperature is maintained at or above 850°C. The charging rate is limited, among others, by the capacity of the primary burners, the induced draft fan, the retention time requirements in the secondary chamber, and the efficiency of the pollution control equipment.

Combustion: In modern incinerators, computer controls adjust operating parameters to maintain optimal conditions. For an incinerator with minimal controls, a well-trained operator must monitor and adjust primary and secondary chamber temperatures, charging rate, and air levels in the primary and secondary combustion chambers (by regulating the air dampers or induced draft fan if possible).

Air pollution control: In modern incinerators, computer controls monitor and regulate the flue gas cleaning system. For an incinerator with minimal controls, a well-trained operator must monitor the opacity, carbon monoxide levels, oxygen concentrations, hydrogen chloride concentrations, and other parameters specific to the air pollution control equipment. For example, for venturi scrubbers, the operator must monitor the venturi pressure drop, liquid flow rate and fan static pressure. For fabric filters, the operator must monitor the flue gas temperature and pressure drop through the unit. For dry systems, the sorbent feed rate, air flow rate, and acid gas concentrations should be monitored. Among the key parameters for an electrostatic precipitator are the gas inlet temperature, particulate resistivity, and the primary and secondary voltages and currents. If these parameters fall outside a recommended range, the operator should make adjustments according to the manufacturer's instructions.

Ash removal: Modern incinerators have automated ash removal systems such as ash augers or screws that deposit the ash into containers. Some systems use wet sumps below the ash discharge chute; the chute extends below the water line to cool the ash and prevent releasing ash particles into the environment. Other systems have a water spray to wet the ash lightly before removal. For manually operated batch incinerators, the system is usually allowed to cool for as long as eight hours before the operator can remove the ash. Due to the toxicity of the bottom ash, operators must wear personal protection equipment when removing the ash. The incinerator ash should then be disposed of properly.

#### *11.3.8.6 Installation Requirements*

The construction and installation of an incinerator entails the following:

- Construction of the foundation, enclosure and ventilation
- Construction or assembly of the refractory layers, steel casing, grates, and insulation of the combustion and post-combustion chambers, as well as the breeching (refractory-lined channels)
- Assembly of the burners, fuel supply systems, air dampers and induced draft fans
- Connection of the electrical controls and air compression system for pneumatic controls
- Addition of the waste charging system, heat recovery boiler if used, and ash sump
- Installation of the flue gas cleaning system and its accessories, including wastewater treatment system if needed, monitoring sensors and electrical controls
- Construction and connection of the stack or chimney.

#### *11.3.8.7 Maintenance Requirements*

Maintenance requirements vary considerably according to the type of incinerator and air pollution control device used. Due to the high temperatures and because incinerator flue gas is very acidic and corrosive, maintenance and repair of incinerators are essential for optimal operation. The maintenance schedule below is provided as an example.

##### Sample hourly maintenance schedule

- (a) Inspect and clean ash removal conveyor
- (b) Inspect water level in the water quench pit and fill as required.

Sample daily maintenance schedule

- (a) Check operation of the opacity monitor, oxygen monitor and thermocouples
- (b) Inspect and clean underfire air ports
- (c) Inspect limit switches for obstruction
- (d) Inspect charging door seals for wear, closeness of fit and air leakage
- (e) Clean the ash pit and sump.

Sample weekly maintenance schedule

- (a) Inspect and clean heat recovery boiler tubes
- (b) Inspect and clean blower intakes
- (c) Inspect and clean burner flame rods (for gas fired units) and flame sensors
- (d) Lubricate latches, hinges, hopper door pins, and ram feeder carriage wheels
- (e) Inspect and clean heat recovery induced draft fan; check for corrosion and adjust V-belt drives and chains.

Sample bi-weekly maintenance schedule

- (a) Check hydraulic fluid in the hydraulic system and replace as needed
- (b) Lubricate ash removal conveyor bearings
- (c) Inspect and clean all fuel trains and burners
- (d) Inspect and clean control panels.

Sample monthly maintenance schedule

- (a) Inspect external surfaces of hot areas and stack for indications of refractory loss
- (b) Inspect and repair minor wear areas in the internal refractory lining
- (c) Inspect internal ram faces for wear
- (d) Inspect and vacuum particulate matter from the secondary chamber floor
- (e) Lubricate air blowers, induced draft fans, and hydraulic cylinder attachments
- (f) Inspect and adjust burner pilot lights.

Sample semi-annual maintenance schedule

- (a) Inspect and re-paint hot external surfaces (with high temperature paint) and cold external surfaces as needed
- (b) Inspect, clean and lubricate chains.

A typical maintenance schedule for a wet scrubber is shown below:

Sample daily maintenance schedule

- (a) Check for proper operation and leakage in the scrubber liquid pump and variable throat activator
- (b) Check scrubber liquid lines, mist eliminator pressure lines, and reagent feed and repair if needed
- (c) Check for proper operation of fan, fan bearings and fan belt.

Sample weekly maintenance schedule

- (a) Check oil level, oil color and temperature of the fan; lubricate
- (b) Check oil level of scrubber liquid fan and lubricate pump motor bearings
- (c) Check damper air purge system for proper operation.

Sample monthly maintenance schedule

- (a) Inspect duct work, fan and motor bearings for leaks, cracks and loose fittings
- (b) Inspect and clean fan blades and internal housing
- (c) Check the drain chain drive mechanism
- (d) Inspect and clean pipes and manifolds and repair if needed
- (e) Check dampers for leakage
- (f) Check spray bars for nozzle wear and plugging; clean as required
- (g) Check pressure gauges for accuracy
- (h) Inspect the main body of the scrubber for material build-up, abrasion or corrosion; clean as needed.

Sample semi-annual maintenance schedule

- (a) Inspect fan, pump, motor, drag chain bearings, and gear reducers for clearance, wear, pitting, and scoring; check also for leaks, cracks and loose fittings
- (b) Check flow meters for accuracy
- (c) Check damper drive mechanism for proper operation and align if needed
- (d) Check damper seals, bearings, blades and blowers for wear and leakage.

A typical maintenance schedule for a baghouse filter is shown below:

Sample daily maintenance schedule

- (a) Check exhaust stack, manometer pressure, compressed air system, damper valves, rotating equipment and drives, and dust removal system
- (b) Observe all indicators on the control panel for proper operation of subsystems.

Sample weekly maintenance schedule

- (a) Check filter bags for tears, holes, abrasion, proper fastening, bag tension, and dust accumulation
- (b) Check cleaning system and cycle times; check compressed air lines
- (c) Check hoppers for bridging or plugging, and check screw conveyor.

Sample monthly maintenance schedule

- (a) Check shaker mechanism for loose bolts and check fans for corrosion and material build-up; check V-belts and chains for tension and wear
- (b) Check accuracy of monitors.

Sample quarterly maintenance schedule

- (a) Inspect the inlet plenum
- (b) Check gaskets in all access doors
- (c) Check shaker mechanism such as tube hooks, bushing, etc.

Sample semi-annual maintenance schedule

- (a) Lubricate all motors and fans.

Sample annual maintenance schedule

- (a) Check all bots and welds
- (b) Inspect the entire system thoroughly, clean and re-paint where necessary.

### 11.3.9 ALKALINE HYDROLYSIS TECHNOLOGIES

#### *11.3.9.1 Process Description*

Alkaline hydrolysis or alkaline digestion is a process that converts animal carcasses, human body parts and tissues into a decontaminated aqueous solution. The alkali also destroys fixatives in tissues and various hazardous chemicals including formaldehyde, glutaraldehyde and chemotherapeutic agents. The technology uses a steam-jacketed, stainless steel tank and a basket. After the waste is loaded in the basket and into the hermetically sealed tank, alkali (sodium or potassium hydroxide) in amounts proportional to the quantity of tissue in the tank is added along with water. The contents are heated to between 110° to 127°C or higher while being stirred. Depending on the amount of alkali and temperature used, digestion times range from six to eight hours. Low-pressure alkaline digestion units are also available. They generally have longer operating times.

The technology is designed for tissue wastes including anatomical parts, organs, placenta, blood, body fluids, specimens, human cadavers and animal carcasses. The process has been shown to destroy prion waste. The byproducts of the alkaline digestion 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. An excess of hydroxide could lead to a high pH of the liquid waste. Alkaline hydrolysis units have been designed to treat from 10 kg to 4500 kg per batch. The technology has been approved for the destruction of prion waste when treated for at least six hours.<sup>157</sup>

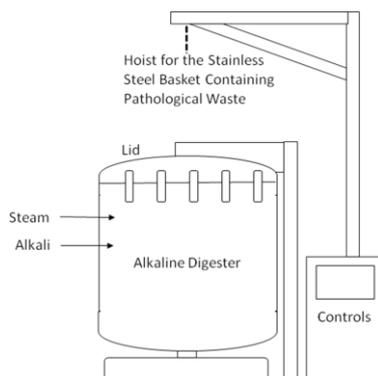


Figure 11.14. Alkaline Tissue Digester (BioSafe Engineering / WR<sup>2</sup>)

### 11.3.9.2 Types of Waste Treated

Alkaline hydrolysis is primarily intended for pathological waste, organs, tissues, cadavers, anatomical parts and contaminated animal carcasses. However, it can also treat biological stocks, cultures, liquid blood, body fluids, and other types of infectious waste. Moreover, the process has been shown to degrade aldehydes, such as formaldehyde and glutaraldehyde waste which are commonly used in healthcare and research settings and may be found in pathological and animal wastes. Many chemotherapeutic agents, such as Cyclophosphamide, Chlorambucil, Melphalan, Uracil Mustard, Daunomycin, etc., are also destroyed by alkaline hydrolysis.<sup>158</sup>

The treatment system should not be used for wastes containing aluminum, tin, zinc, magnesium, copper, or galvanized iron (as these metals could react to form hydrogen gas), as well as concentrated acids, flammable liquids and organohalogen compounds (especially trichloroethylene), and nitromethane and other similar nitro compounds.

### 11.3.9.3 Range of Capacities

Alkaline hydrolysis technologies can handle from 15 to 4500 kg per load, with treatment cycles ranging from 3 to 8 hours depending on temperature, pressure, alkali concentration, and mixing efficiency.

### 11.3.9.4 Pathogen Destruction

Kaye and co-workers tested the efficacy of alkaline hydrolysis of on animal carcasses (pigs, sheep, rabbits, dogs, rats, mice, and guinea pigs) along with the following microbiological indicator organisms: *Staphylococcus aureus*, *Mycobacterium fortuitum*, *Candida albicans*, *Bacillus subtilis*, *Pseudomonas aeruginos*, *Aspergillus fumigatus*, *Mycobacterium bovis* BCG, MS-2 bacteriophage, and *Giardia muris*.<sup>159</sup> No growth was reported for any of the indicator organisms, corresponding to log<sub>10</sub> reductions ranging from 7 to 9 except for *Giardia* and *Aspergillus*

<sup>157</sup> H. Thacker, "Carcass Disposal: A Comprehensive Review, Chapter 6: Alkaline Hydrolysis. National Agricultural Biosecurity Center. Kansas State University," 2004; "Updated opinion and report on: A treatment of animal waste by means of high temperature (150°C, 3 hours) and high pressure alkaline hydrolysis," Scientific Steering Committee, Health & Consumer Protection Directorate-General, European Commission, 2003.

<sup>158</sup> Technical Data Monograph, Waste Reduction by Waste Reduction, Inc., Indianapolis, Indiana, no date.

<sup>159</sup> "Efficacy of Alkaline Hydrolysis as an Alternative Method for Treatment and Disposal of Infectious Animal Waste," G.I. Kaye, P.B. Weber, A. Evans, and R.A. Venezia, Contemporary Topics (American Association for Laboratory Animal Science) 37(3), 43-46 (1998).

*fumigatus*. *Aspergillus* had a reduction corresponding to about 3 log<sub>10</sub>. Intact *Giardia* cysts could not be detected except for small fragments of what appeared to be cyst wall.

#### 11.3.9.5 Emissions and By-Products

Alkaline hydrolysis converts fats in human or animal parts into soaps. Tissues, organs and body parts are decomposed into peptides, amino acids, soaps, salts, sugars, and ammonia. When the process is complete, a soapy ammonia odor can be detected in the immediate vicinity of the unit and is generally dissipated by natural ventilation.

As the alkaline digestion process decomposes pathological waste into liquid (except for calcium and any metals, plastics or rubber in the waste), the effluents from an alkaline hydrolysis unit can range from 100 liters per load for a 15 kg unit to 24,000 liters per load for a large 4500 kg unit. The effluent has a pH of about 11 and generally has to be discharged at a slow rate, diluted or neutralized by bubbling CO<sub>2</sub> depending on local regulations. Tests of the effluent showed relatively high biological oxygen demand (BOD<sub>5</sub>), chemical oxygen demand, suspended solids, organic nitrogen and ammonia but were within effluent discharge limits.<sup>160</sup>

The solid residues of alkaline hydrolysis are calcium from friable bone fragments, and any plastics, non-reactive metals, rubber, or ceramics. Since the solid residues are sterile, they can be recovered. Calcium from alkaline hydrolysis has been used as a soil conditioner.

The by-products of low pressure alkaline hydrolysis units are generally in the form of a slurry with hard bone fragments. The slurry coagulates and forms a hard solid when it cools.

#### 11.3.9.6 Operational Details

The system can be controlled by a sophisticated computer controller or a well-trained operator. The steps for a typical run are as follows:<sup>161</sup>

Waste loading: The operator attaches the stainless steel basket to an overhead crane (for large systems); the basket is then lowered into the vessel. Animal carcasses and other waste are loaded into the stainless steel basket using the overhead crane. The lid is lowered and clamped onto the vessel.

Alkaline digestion: A predetermined concentration of sodium or potassium hydroxide solution (based on the waste load) is pumped into the vessel. Steam is injected into the steam jacket or vessel. The temperature, heating time and circulation of the alkali solution is automatically controlled as the digestion proceeds for several hours.

Cooling: At the end of the digestion cycle, the controller automatically shuts off the steam. The contents are allowed to cool overnight down to ambient temperatures. In some systems, cooling water can be added.

Effluent discharge: Water is added to rinse the inside of the vessel and dilute the hydrolysate. The effluent can be stored in a holding tank where it can be trickled into the sewer system, neutralized by bubbling CO<sub>2</sub> into the tank, or further diluted before being released into the drain. The operator opens the drain line to release the effluent into the sewer.

Removal of solid residues: The clamps are removed and the lid is opened. The stainless steel basket is removed using an overhead crane (for large systems) and positioned over a nearby dumpster. The operator opens the side door of the steel basket and discards the bone residues directly into a dumpster for disposal as regular waste. Alternatively, the calcium can be recovered, crushed and used for soil conditioning.

---

<sup>160</sup> Data provided to the author by WR<sup>2</sup>, Indianapolis, Indiana in 2005.

<sup>161</sup> Based on the BioSafe Engineering / WR<sup>2</sup> technology.

### 11.3.9.7 Installation Requirements

The typical installation requirements are:

- Enclosure and foundation
- Sewer
- Water supply
- Steam (unless an electric or gas-fired steam generator is used)
- Electrical connections
- Air
- Phone line.

### 11.3.9.8 Maintenance Requirements

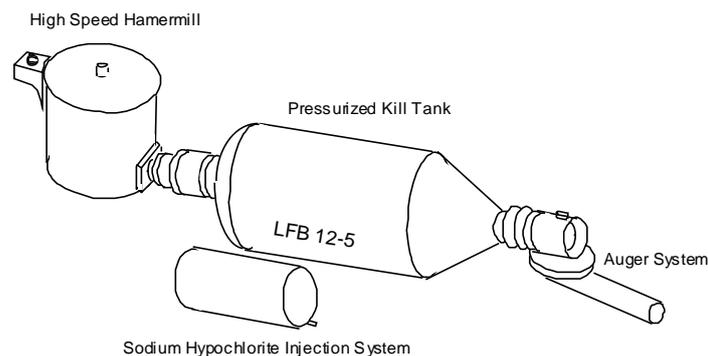
A typical preventive maintenance schedule includes visual checks on piping, valves, filters, O-rings, as well as checking and lubricating lid gaskets. For units that use a pump seal barrier fluid, the barrier fluid should be checked regularly for leaks. Other maintenance requirements include oil changes, O-ring replacements, and checking the accuracy of the pump pressure gauge and other monitoring sensors. The circulating pump or mechanical mixing arm is generally the part that requires the most maintenance.

## 11.3.10 CHEMICAL TREATMENT SYSTEMS

### 11.3.10.1 Process Description

This discussion on chemical treatment is about treatment of healthcare waste and does not refer to environmental cleaning, disinfection of medical instruments or surface disinfection in health facilities. Chemical disinfection has been used for the treatment of healthcare waste. This treatment usually resulted in disinfection rather than sterilization. The speed and efficiency of chemical disinfection will depend on operational conditions, including the type of chemical disinfectant used, its concentration, the contact time between the disinfectant and the waste, the extent of contact, the organic load of the waste, operating temperature, and factors that may affect the efficacy of the disinfectant such as humidity and pH. These technologies have become less widely used due to concerns pertaining to environment and occupational safety.

Commercial, self-contained and automatic systems have been developed for healthcare waste treatment. In the past, solutions of sodium hypochlorite or bleach ( $\text{NaOCl}$ ) were the most commonly used disinfectant for treating healthcare waste. However, concerns have been raised regarding toxic byproducts associated with the use of large quantities of hypochlorite, in particular, the reactions between chlorine/hypochlorite and organic matter that could produce trihalomethanes, haloacetic acids, chlorinated aromatic compounds, chloramines, and dioxins in downstream wastewater. Another issue is making sure that chlorine levels are maintained, which may be difficult when waste streams have a high organic load.



*Figure 11.15. Sodium Hypochlorite Chemical Treatment System*

Chlorine dioxide, ClO<sub>2</sub>, is an alternative to hypochlorite. Since chlorine dioxide in air is an unstable gas that decomposes to form toxic chlorine gas and heat, it is generated and used on site using sodium chlorite, sodium chlorate, or electrochemical means. It is stable as a dilute aqueous solution. Chlorine dioxide has the advantage of forming chlorite ion which decomposes to form salt. Many organic compounds such as ammonia, alcohols, and aromatic compounds do not react readily with chlorine dioxide thereby avoiding some of the toxic byproducts associated with hypochlorite.

Other chemicals that have been used for disinfection of healthcare waste are peracetic acid, iodophors, aldehydes, lime-based powders or solutions, ozone gas, quarternary ammonium salts and phenolic compounds. All of these pose serious occupational hazards and most can have adverse environmental impacts. Formaldehyde and ethylene oxide are no longer used for waste treatment because of the significant health hazards related to their use.

Internal shredding of solid healthcare waste before or during disinfection is necessary to ensure good contact between the disinfectant and contaminated waste surfaces. Rotating-blade shredders are used most commonly to increase the surface area of contact, eliminate voids in the waste load, render anatomical parts unrecognizable and reduce the volume of waste.

The corrosiveness or toxic properties of chemical disinfectants are an important consideration. Gloves, protective eyewear and facemasks may be needed when handling the chemicals, which must be stored in safe, well-ventilated locations. Their stability and shelf life of disinfectants should also be taken into account. The chemical treatment area for the waste must be well ventilated and equipped with emergency eye wash or shower stations.

#### *11.3.10.2 Types of Waste Treated*

Chemical disinfection has been used for treating liquid waste such as blood, urine, stools or hospital sewage. Infectious healthcare wastes, including microbiological cultures and sharps, have also been disinfected chemically but using the proper concentration and ensuring contact of the disinfectant with contaminated surfaces are important.

#### *11.3.10.3 Range of Capacities*

Commercial chemical treatment technologies for healthcare waste have capacities ranging from 40 kg/hour to 700 kg/hour.

#### *11.3.10.4 Pathogen Destruction*

The effectiveness of chlorine and chlorine compounds such as sodium hypochlorite has long been established.<sup>162</sup> Chlorine dioxide, an alternative to hypochlorite, is also a recognized broad-spectrum disinfectant.<sup>163</sup> It has been shown to inactivate bacteria, viruses such as HIV and poliovirus, protozoa, fungi, and algae. Some tests have indicated that chlorine dioxide may be more effective than chlorine in the inactivation of

---

<sup>162</sup> See for example, G.R. Dychdala, "Chlorine and Chlorine Compounds," Chapter 7 in *Disinfection, Sterilization, and Preservation*, S.S. Block (editor), 5<sup>th</sup> Edition, Lippincott Williams & Wilkins, Philadelphia, PA, 2001.

<sup>163</sup> J.E. Knapp and D.L. Battisti, "Chlorine Dioxide," Chapter 11 in *Disinfection, Sterilization, and Preservation*, S.S. Block (editor), 5<sup>th</sup> Edition, Lippincott Williams & Wilkins, Philadelphia, PA, 2001; C.L. Latshaw, "Chlorine dioxide: effective broad-spectrum biocide for white-water systems," *TAPPI Journal* 78, 163-166, 1994; R.W. Farr and C. Walton, "Inactivation of human immunodeficiency virus by a medical waste disposal process using chlorine dioxide," *Infection Control in Hospital Epidemiology* 14, 527-529, 1993.

coliform, certain oocysts, and some bacterial spores.<sup>164</sup> Tests of a chlorine dioxide technology operating in the range of about 20 to 35 ppm ClO<sub>2</sub> achieved a 6 Log<sub>10</sub> reduction of *S. aureus*, *P. aeruginosa*, MS2 bacteriophage, *C. albicans*, and *P. crysogenum*, as well as a 4 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus* spores.<sup>165</sup> Simulating the conditions in the technology, a 35.4 ppm ClO<sub>2</sub> concentration reduced the Polio I virus in 5% serum by >3 Log<sub>10</sub> within 3 minutes and a 30 ppm concentration resulted in a 6 Log<sub>10</sub> reduction of HIV in the presence of blood and surrogate medical waste.<sup>166</sup> Since bacillus spores are often used to establish biocidal properties, various studies have investigated the concentration and contact time needed for different levels of spore reduction. The Table below gives examples of data on the inactivation by chlorine dioxide of some resistant bacterial spores.

Table 11.2. Spore Inactivation Data for Chlorine Dioxide<sup>167</sup>

Spore	Chlorine Dioxide (ClO <sub>2</sub> ) concentration (mg/L)	Contact Time (minutes)	Log <sub>10</sub> Spore Reduction
<i>Geobacillus stearothermophilus</i>	20	90	5
	25	12	4
<i>Bacillus atrophaeus</i> (proprietary formulation)	0.75	5	4.5
	3	10	4
	2.6	25	4
	1	30	4
	2	10	3
<i>Bacillus cereus</i> F4810/72	50	50	6.5
<i>Bacillus macerans</i>	20	11	4
<i>Bacillus mesentericus</i>	18	30	4
	11	30	4
	2	10	3
<i>Clostridium botulinum</i>	125	14	3

Tests done for a chemical treatment technology using a proprietary mixture of glutaraldehyde and quarternary ammonium compounds showed that a greater than 6 Log<sub>10</sub> kill can be achieved at a given concentration 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.<sup>168</sup>

### 11.3.10.5 Emissions and By-Products

The emissions and by-products of chemical treatment technologies depend on the type of disinfectant used. Chemical-based technologies operate as closed systems or under negative pressure passing exhaust gases

<sup>164</sup> P.V. Roberts, E.M. Aieta, J.D. Berg, and B.M. Chow, "Chlorine Dioxide for Wastewater Disinfection: A Feasibility Evaluation," Stanford University Technical Report 251, October 1980; G.M. Ridenour, R.S. Ingols, and E.H. Armbruster, "Sporicidal Properties of Chlorine Dioxide," *Water & Sewage Works* 96(8):279, 1949; D.G. Korich et al. "Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on *Cryptosporidium parvum* oocyst Viability," *Appl. Environ. Microbiol.* 56:1423-1428, 1990.

<sup>165</sup> E.C. Cole, R.M. Hall and K.E. Leese, "Antimicrobial effectiveness of the Condor® Medical Waste Treatment System," Report No. 94C-5148-003 prepared for Winfield Environmental, Research Triangle Institute, Research Triangle Park, NC; presented at the 35<sup>th</sup> Biological Safety Conference, San Francisco, CA, October 1992.

<sup>166</sup> "Laboratory Report: Polio I Virucide on Chlorine Dioxide," Gibraltar Biological Laboratories, Fairfield, NJ, 1992; R.W. Parr and C.L. Walton, report to Winfield Corporation, West Virginia University, Morgantown, WV, 1992.

<sup>167</sup> F. Leo, P. Poisson, C.S. Sinclair, and A. Tallentire, "Design, development and qualification of a microbiological challenge facility to assess the effectiveness of BFS aseptic processing," *PDA Journal of Pharmaceutical Science Technology* 59, 33-48, 2005; K. Botzenhart, G. M. Tarcson and M. Ostruschka, "Inactivation of Bacteria and Coliphages by Ozone and Chlorine Dioxide in a Continuous Flow Reactor," *Water Science & Technology* 27(3-4), 363-370, 1993; M.S. Harakeh, A. Illescas, and A. Matin, "Inactivation of bacterial by Purogene," *Journal of Applied Bacteriology* 64, 459-463, 1988; P.M. Foegeding, V. Hemstapat and F.G. Giesbrecht, "Chlorine dioxide inactivation of *Bacillus* and *Clostridium* spores," *Journal of Food Science* 51: 197-201, 1986; Ito, K.A. and M.L. Seeger, "Effect of germicides on microorganisms in can cooling waters," *J. Food Protect.* 43(6): 484-487, 1980.

<sup>168</sup> 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.

through HEPA or other filters. Safeguards should be taken to prevent occupational exposures to the chemical disinfectant 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 stored in concentrated form increases the potential hazard. Since chemical processes usually require shredding, the design should ensure that there is no release of pathogens through aerosol formation during shredding.

Sodium hypochlorite breaks down to form table salt but the disposal of large quantities of chlorine and hypochlorite in wastewater has raised concern regarding the formation of toxic and eco-toxic trihalomethanes, haloacetic acids, chlorinated aromatic compounds, chloramines and possibly dioxins in the discharged wastewater downstream. Sodium hypochlorite can irritate the respiratory tract, skin, and eyes. The OSHA permissible exposure limit is 0.5 ppm (time-weighted average). Local exhaust ventilation and personal protection equipment are important.

Chlorine dioxide decomposes to chlorite ion which breaks down further to form salt. Because many organic compounds do not react readily with chlorine dioxide salt, the levels of chlorinated byproducts in the wastewater could be reduced. Chlorine dioxide is a poisonous gas that is readily soluble in water. It has a maximum recommended exposure limit of 0.1 ppm (8-hour average). Proper ventilation and personal protection equipment are also vital.

Some commercial technologies use a mixture of glutaraldehyde and quarternary ammonium compounds. Glutaraldehyde is a severe irritant to skin and mucous membranes. Its vapors can cause a stinging sensation in the eyes, with excess tear production and redness of the conjunctiva, sensitization of the skin and allergic reactions from chronic exposures, and burns to the respiratory tract. Glutaraldehyde is a strong biocide and toxic to aquatic species, which could result in adverse environmental impacts. The aquatic biodegradation (aerobic) half-life of glutaraldehyde is about 10.6 hours. Quarternary ammonium ions can cause skin and respiratory irritation. The biodegradation half-life of quarternary ammonium compounds (such as didecylidimethyl ammonium chloride) in river water is in the order of a day to several days. Proper personal protection equipment should be used when handling these chemicals. The technology should only be used in a well-ventilated area.

#### *11.3.10.6 Operational Details*

Chemical treatment technologies generally have an integrated monitoring and control system to adjust concentrations and other parameters thereby ensuring optimal operating conditions. A typical operation of a chemical treatment system is as follows:

Waste loading: The operator places the waste in a hopper. Some technologies use an automatic waste tipper.

Internal shredding or milling: The waste enters the shredding or milling section wherein it is ground into smaller pieces.

Exposure to the chemical disinfectant: Regulated amounts of the chemical disinfectant are pumped into the vessel containing the shredded waste. Alternatively, the shredded waste can fall into a reservoir already containing the chemical disinfectant at the optimal concentration, or the shredded waste is flushed along with the chemical disinfectant into a line that is long enough to provide the correct contact time.

Contact Time: The shredded waste is allowed to mix with the disinfectant for a predetermined contact time. Mixing can be done by a re-circulating pump, a rotating mixer or an auger.

Dewatering and recycling of disinfectant: After the contact period is completed, the treated waste goes through a dewatering section which separates liquid and solid. This can be done using a compaction auger, filter sack, strainer, press, centrifuge, or other solid-liquid separator. If the liquid disinfectant is recycled, the concentration of the disinfectant should be monitored and more chemical added as necessary to maintain optimum concentrations.

**Disposal:** The relatively dry, treated solid waste is deposited into a container for proper disposal. The wastewater, which may have to be diluted, is discharged into the sanitary sewer.

**Documentation:** The operating parameters during the treatment cycle are documented.

#### 11.3.10.7 *Installation Requirements*

The typical installation requirements are:

- Adequate floor space and foundation
- Electrical connections
- Water supply
- Drain to the sanitary sewer
- Ventilation possibly including local exhaust ventilation
- Separate well-ventilated area for chemical storage
- Eyewash station, sink, and safety shower as needed; storage area for personal protection equipment.

#### 11.3.10.8 *Maintenance Requirements*

For a small chemical treatment unit, daily and weekly preventive maintenance requires approximately 5-10 minutes.<sup>169</sup> Preventive maintenance of moving parts is important. These include shredders or hammer mills, pumps, conveyors, motors, mixers, etc. Furthermore, disinfectant feed lines, hoppers, reservoirs, pipes, filter screens, the solid-liquid separator and discharge chutes should be inspected and kept clean. Valves, metering pumps, monitoring sensors, and controls should be checked for proper functioning.

### 11.4 OTHERS

In this section, some relatively new technologies, emerging technologies or technologies that may come into wider use in the future are briefly described. Ozone (O<sub>3</sub>) is a strong oxidant that can destroy microorganisms and degrades readily to regular oxygen. In past experiments, a portable pilot-scale unit used an electrochemical ozone generator using water as a source to produce about 2 kg of ozone per day at concentrations as much as 18 wt% ozone under pressure.<sup>170</sup> 45 kilograms of waste were shredded and exposed to the ozone gas for four hours achieving the minimum reduction of *B. atrophaeus* spores.

Recently, a new ozone-based system operating at room temperature was developed with a capacity of about 1000 kg per hour.<sup>171</sup> In the automated operation, waste is fed into the system and is shredded to 19 mm size particles. Ozone is mixed with aerosolized water creating a fog in the treatment chamber. After shredding, the waste particles fall through the ozone-water fog onto the chamber floor where they sit for 6 minutes. The treated waste is then pushed into a transport container by a hydraulic ram. When the container fills, the chamber is purged of ozone gas and the container is detached and transported directly to a sanitary landfill for waste disposal. A catalytic converter and heater are used to decompose any residual ozone. The technology has atmospheric ozone monitors for occupational safety. Installation requirements include a shaded enclosure, a ventilation system including forced-air ventilation for emergencies, electrical power and a water supply. During peak operation, it consumes about 37 kWh/hr and about 8 liters of water per hour. The technology has been approved in some jurisdictions for pathological and microbiological waste.

---

<sup>169</sup> Based on the MCM Sterimed.

<sup>170</sup> T.D. Rogers, "An Ozone-Based System for Decontamination and Treatment of Red Bag Medical Waste," Lynntech, Inc., College Station, TX, and communications to the author, 1998.

<sup>171</sup> "Ozone Disinfection Applications," Ozonator Industries, Regina, SK Canada; <http://www.ozonatorindustries.ca/> and information provided to the author by Peter Klaptchuk, Ozonator Industries.

Dry chemical treatment using physical destruction in a horizontal shredder and exposure to a dry inorganic (calcium oxide-based) disinfectant powder has been used in the past.<sup>172</sup> Microbial inactivation tests showed a greater than 6 log<sub>10</sub> kill for *B. atrophaeus* and *G. stearothermophilus*. Waste was shredded and the powder was added with a small amount of water. The process took about six minutes and did not produce a liquid effluent. Other past technologies used proprietary disinfectant powders and lime slurries.

In addition to alkaline hydrolysis, a new process called promession has emerged which could potentially be used for pathological waste, tissues, cadavers, and animal waste.<sup>173</sup> The process involves freezing body parts or cadavers at -18°C, then submerging the frozen remains into liquid nitrogen at -196°C, transferring the brittle remains onto a mechanical shaker or vibrating mat where the mechanical action causes the remains to shatter into an organic powder, placing the powder in a vacuum chamber for drying, recovering any recyclable materials such as metals (magnetic separators can be used), and final burial in a biodegradable container. The technology has been used as an alternative to traditional burials or cremation but has the potential for application in the destruction of pathological wastes.

In developing countries, burial (interment) in cemeteries or specially designated areas remains a viable option for dealing with pathological waste, body parts, and cadavers. WHO recommends that religious and cultural norms, community acceptance and ground conditions should be considered.<sup>174</sup> Burial areas should not be near groundwater drinking sources and residences. Burial depth should be 1.5 to 3 m deep but the bottom should be at least 1.5 m above the groundwater table, with at least a 1 m covering of soil. Composting and vermiculture, especially for small tissues and placenta waste, is another option for communities where these are acceptable.<sup>175</sup>

## 11.5 SPECIFIC CONSIDERATIONS FOR DEVELOPING COUNTRIES

### 11.5.1 ENVIRONMENTAL AND OCCUPATIONAL SAFETY ASPECTS

A survey of primary healthcare centers in Tanzania found that, in one area, 70% of healthcare centers used poor quality incinerators, or burned waste in pits or on open ground.<sup>176</sup> Over half the disposal sites were unfenced and close to residential areas. Similar situations were found in South Africa, Mozambique, and Swaziland. In Kenya, a survey of medical waste incinerators constructed in 2002 revealed that most incinerators were improperly operated and most of the incinerators had some technical defects.<sup>177</sup> A study in India looked at eight medical waste incinerators that were less than two years old.<sup>178</sup> The survey found problems of smoke emissions, some coming out of the charging doors; large quantities of unburned material in the ash; siting of incinerators in inappropriate locations (e.g., in the children's playground, beside the hospital staff quarters or near a primary school) and improper disposal (e.g., ash dumped in the hospital yard).

---

<sup>172</sup> MMT3000 and Cold-Ster disinfectant described in W.L. Turnberg, *Biobazardous Waste: Risk Assessment, Policy and Management*, John Wiley & Sons, Inc. New York, NY, 1996.

<sup>173</sup> Information obtained from Promessa Organic AB, Färjeläget 7600, 474 96 Nösund, Sweden; www.promessa.se

<sup>174</sup> "Disposal of dead bodies," WHO Technical Note for Emergencies No. 8, World Health Organization, Geneva, Switzerland, 2011.

<sup>175</sup> U.B. Mathur, L.K. Verma, L.K. and J.N. Srivastava, "Effects of Vermicomposting on Microbiological Flora of Infected Biomedical Waste," *Journal of ISHWM* 5(1): 21-27, 2006.

<sup>176</sup> S. V. Manyele and T. J. Lyasenga, "Factors affecting medical waste management in low-level health facilities in Tanzania," *African Journal of Environmental Science & Technology* 4(5), 304-318, May 2010; L. Leonard, "Health Care Waste in Southern Africa," Proceeding International Health Care Waste Management Conference and Exhibition, Johannesburg, South Africa, 2003.

<sup>177</sup> E. Taylor, "Rapid Assessment of Small-scale Incinerators," Final Draft, Kenya, July 2003.

<sup>178</sup> J. Emmanuel, G. McRae, and F. Mahmoudi, "Environmentally Responsible Management of Health Care Waste With a Focus on Immunization Waste," Health Care Without Harm, Washington, DC, October 2002; also presented at the Safe Injection Global Network and National AIDS Control Programme Managers in Africa conference, Nairobi, Kenya, September 18-20, 2003.

Many developing countries still use small-scale incinerators with little or no pollution control. They are in response to an immediate need to destroy infectious waste but should be viewed as a short-term interim solution until cleaner state-of-the-art technologies are available. In 2004, the World Health Organization commissioned a screening level health risk assessment for exposure to dioxins and furans from small-scale incinerators.<sup>179</sup> The study found that the expected practice with small-scale incinerators resulted in unacceptable cancer risks under medium usage (two hours per week) or higher. As much as possible, burning polyvinyl chloride plastics and other chlorinated waste should be avoided in these small-scale incinerators and best management practices, such as waste reduction and segregation, should be adopted. The WHO policy of 2004 calls for the promotion of non-burn alternatives as a long-term strategy. The Stockholm Convention requires that priority consideration be given to non-incineration technologies that do not generate dioxins. In the Stockholm Convention guidelines on best available techniques, small-scale single-chamber, drum and brick incinerators were rejected.<sup>180</sup> This Compendium is intended to assist developing countries select appropriate treatment technologies for healthcare waste that meet these and other international standards.

Considerations of occupational safety and health are another important consideration and should always be part of a framework for healthcare 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
- 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
- breakage and spills of infectious waste bags
- chemical exposure.

Other hazards depend on which treatment technology is selected:

- hot surfaces that cause burns
- exposure to 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
- non-ionizing radiation such as 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.<sup>181</sup> The study looked at autoclave, microwave, chemical-mechanical, and pyrolysis-oxidation 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.

---

<sup>179</sup> S. Batterman, "Assessment of Small-Scale Incinerators for Health care Waste," report prepared for the Protection of the Human Environment, World Health Organization, Geneva, 2004.

[www.who.int/water\\_sanitation\\_health/medicalwaste/en/smincinerators.pdf](http://www.who.int/water_sanitation_health/medicalwaste/en/smincinerators.pdf)

<sup>180</sup> Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Geneva, Stockholm Convention Secretariat, United Nations Environment Programme, 2006.

<sup>181</sup> 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," National Institute of Occupational Safety and Health, Cincinnati, OH, November 1997.

Another study by the California Department of Health Services looked specifically at the collection and transport of waste and treatment at a large-scale autoclave central treatment plant.<sup>182</sup> 72% of the occupational injuries were due to ergonomic stressors and sharps hazards. The ergonomic stressors, not related to the autoclave technology as such, were a result of manual heavy lifting of waste containers. Sharps injuries were due to the spilling of sharps waste. Other occupational problems were exposure to chemicals and to ionizing radiation as a consequence of improper segregation by the waste generators. Workers were also exposed to heat, odor, noise and carbon monoxide from forklifts.

Healthcare 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, 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.

Table 11.3 below gives an indicative summary of the environmental and occupational safety aspects of the generic treatment technologies. Specific technologies, however, have to be evaluated on their own merits.

*Table 11.3. Environmental and Occupational Safety Aspects of Treatment Technologies*

Technology	Environmental Concerns			Occupational Safety Concerns	
	Air	Water	Solid Residue		Notes
Autoclaves	X	XX	X	XX	High pressure
Hybrid autoclaves	X	XX	X	XX	High pressure
Continuous steam treatment systems	X	X	X	X	
Batch microwave technologies	X	X	X	X	
Continuous microwave technologies	X	X	X	X	
Frictional heat treatment systems	X	X	X	X	
Dry heat treatment systems	X	X	X	X	
Incinerators	XXX	XX*	XXX	XXX	Air emissions, ash
Alkaline hydrolysis technologies	X	XXX	X	XX	High pressure, alkali
Chemical treatment systems	XX	XX	X	XXX	Chemical exposure

Legend: X – minimal concerns, XX - some concerns, XXX - significant concerns; \* if the incinerator’s flue gas cleaning generates wastewater that has to be treated

### 11.5.2 SOCIAL ASPECTS AND JOB POTENTIAL

The selection of treatment technologies requires consideration of social aspects including the potential for job creation. The Rio Declaration and the principle of prior informed consent promote the participation of all citizens in environmental decision-making, as well as appropriate access to information on hazardous materials and activities, and facilitation of public awareness.<sup>183</sup> At least four areas of major social concern should be evaluated.

- Impact on social resources

<sup>182</sup> P. Sutton et al., “Transforming Medical Waste Disposal Practices to Protect Public Health: Worker Health and Safety and the Implementation of Large-Scale, Off -Site Steam Autoclaves,” Department of Health Services, State of California, February 2006.

<sup>183</sup> Principle 10 of the Rio Declaration on Environment and Development, United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, June 3-14, 1992; International Workshop on Methodologies Regarding Free Prior and Informed Consent and Indigenous Peoples, Department of Economic and Social Affairs, United Nations, New York, January 17-19, 2005.

- Will environmental releases impact public health?
  - Will the wastewater pollute surface water or groundwater?
  - Will the site for the technology disrupt the ecosystem?
  - Will the technology have a detrimental effect on natural resources (e.g. acid precipitation of incinerator emissions)?
  - What will be the impact of odors on the adjacent neighborhood?
  - What will be the impact of noise on the adjacent neighborhood?
  - How will the plant affect traffic in the area?
- Impact on cultural values
    - Is the technology socially acceptable?
    - Does the technology violate some cultural or religious norm (e.g., alkaline digestion or steam treatment of body parts)?
    - Will the plant have an adverse aesthetic or visual impact?
    - Is the presence of a visible stack acceptable?
- Impact on social cohesion and economic structure
    - What is the economic impact of the plant?
    - Will the plant provide employment for the community?
    - Will new workers from outside the community and their dependents have a negative impact on the community?
    - Will the new plant result in the dislocation of people?
    - Will the technology put inordinate demands of resources, such as fuel, water or electricity?
    - Is there a potential for a catastrophic failure with wide-ranging consequences for the community?
- Impact on social equity
    - Will there be negative impacts that disproportionately affect some sector(s) of the community?
    - Will the deployment of the technology have potential effects on indigenous people, the poor, children and women?

The potential for employment depends in part on the capacity of the technology; large capacity technologies can be installed in central treatment plants which necessitate a large workforce. On the other hand, highly automated technologies reduce the need for a large workforce. Very sophisticated technologies, such as a large high-tech incinerator with computer controls, still need a large workforce but it may mean the importation of trained technicians from outside the community. Operation of other technologies, like autoclaves, is relatively easy to learn and does not require a high level of education, hence local people could be hired and trained. Table 11.4 below gives a qualitative summary of social concerns related to technologies. The job creation potential is based mainly on the capacity range.

Table 11.4. Social Aspects of Treatment Technologies

Technology	Potential for Job Creation	Social Concerns	Notes
Autoclaves	√√	X	There may be community opposition to incinerators in neighborhoods. It may not be culturally or religiously acceptable for treating body parts. The community may be concerned with chemical accidents and releases
Hybrid autoclaves	√√	X	
Continuous steam treatment systems	√√	X	
Batch microwave technologies	√	X	
Continuous microwave technologies	√√	X	
Frictional heat treatment systems	√√	X	
Dry heat treatment systems	√	X	
Incinerators	√√	X X X	
Alkaline hydrolysis technologies	√√	X X X	
Chemical treatment systems	√	X X	

Legend: √ - small potential, √√ - medium potential; X - minimal concerns, XX - some concerns, XXX - significant concerns

### 11.5.3 INVESTMENT AND OPERATING COSTS

The capital and operating costs of treatment technologies are comprised of many items as listed in Table 11.5. Some items may not apply depending on specific technologies and situations.

Table 11.5. Capital and Operating Cost Items

Capital Costs	
Equipment	Equipment purchase cost including taxes Auxiliary equipment (e.g., computer controls, boilers, shredders, compactors, air pollution control devices, required instrumentation, etc.) Cost of accessories (e.g., bins, carts, bin dumpers, trolleys, weighing scale, roll-off containers, etc.) Spare parts
Shipment	Costs associated with shipment, including customs fees, insurance, etc. Storage charges
Site preparation	Cost of land and right of way New construction or renovation of treatment plant and waste storage area Electrical service including lighting Provision of utilities (water, steam) and sewer drain Heating and ventilation
Indirect costs	Project management Architecture and engineering Consultancy fees Construction fees Permitting and other legal fees Start-up costs, performance testing, commissioning Regulatory testing
Operating Costs	
Labor	Operators' wages and benefits Supervisor wages and benefits
Utilities	Electricity Steam Diesel, natural gas, LPG or other fuels Water Compressed air
Supplies	Color-coded plastic bags, boxes or containers Sharps containers Personal protective equipment Labels Disinfectants and cleaning supplies Chemicals (for chemical treatment or for flue gas cleaning) Spill kits
Maintenance	Materials and replacement parts Maintenance labor or service costs Maintenance of vehicles
Repairs	Materials and replacement parts Repair labor or service costs
Landfill costs	Transportation costs Tipping or disposal fees
Indirect costs	General and administrative costs Insurance Annual permitting fees Periodic training Taxes Cost of periodic emission testing or validation testing

With regards to shipment, many countries use Incoterms (International Commercial terms) rules. The rules defined by Incoterms 2010 include: EXW or Ex Works, wherein the buyer pays all the transportation costs from the premises of the seller and bears the risks; FOB or Free on Board, wherein the seller loads the goods on board a maritime vessel designated by the buyer, clears the goods for export, and shares the cost and risk when the goods are on board; CFR or Cost and Freight, wherein the seller pays the costs and freight to a designated

port of destination and transfers the risk to the buyer once the goods are loaded on the vessel; CIF or Cost, Insurance and Freight, which is the same as CRF except that the seller also pays for insurance; and DDP or Delivered Duty Paid, wherein the seller pays all costs including duties and taxes to deliver the goods to a specific place designated by the buyer. Incoterms 2000 rules include DDU or Delivered Duty Unpaid, wherein the seller delivers goods to a designated place and the buyer pays for unloading, duties, customs clearance, and transport beyond the designated place unless stated otherwise in the contract.

The figures below are based on capital costs provided by vendors around the world. Capital costs were plotted against capacity in kg per hour. The dark lines give the average costs calculated by linear regression analyses. The dashed curves are the boundaries of the lowest and highest data points. In general, they do not include construction or renovation of the treatment space and commissioning. Note that the range of capital costs of waste treatment autoclaves shifted when the capacities exceeded 100 kg/hr.

Figure 11.16. Cost of a Waste Treatment Autoclave (Capacity < 100 kg/hr)

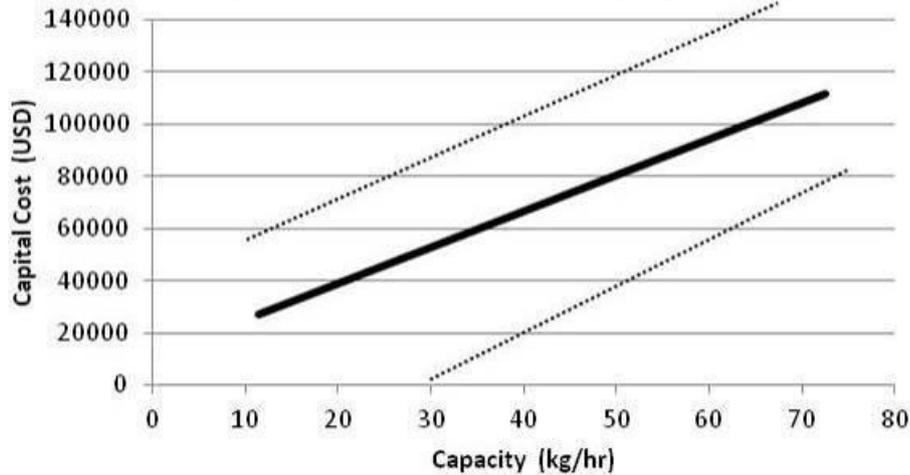


Figure 11.17. Cost of a Waste Treatment Autoclave (Capacity > 100 kg/hr)

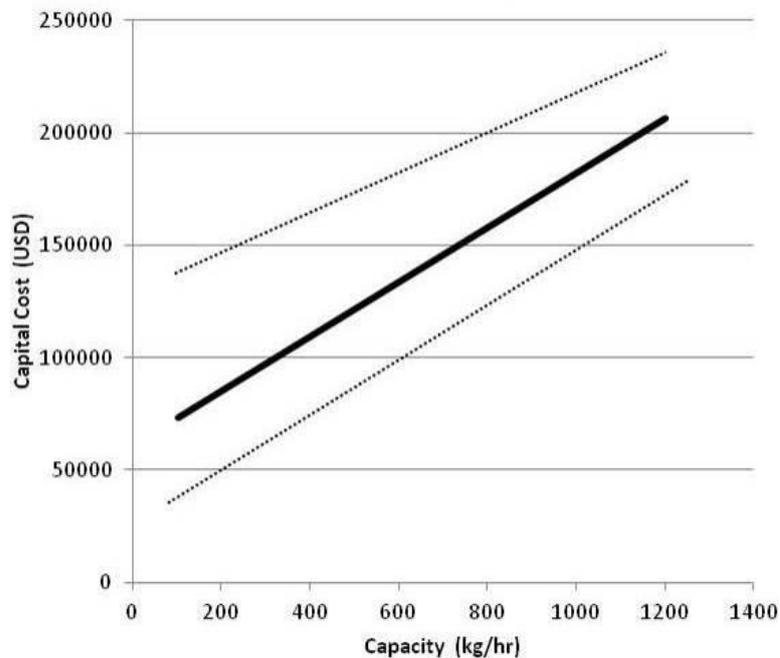


Figure 11.18. Cost of a Waste Treatment Autoclave with a Shredder or Compactor (Capacity < 100 kg/hr)

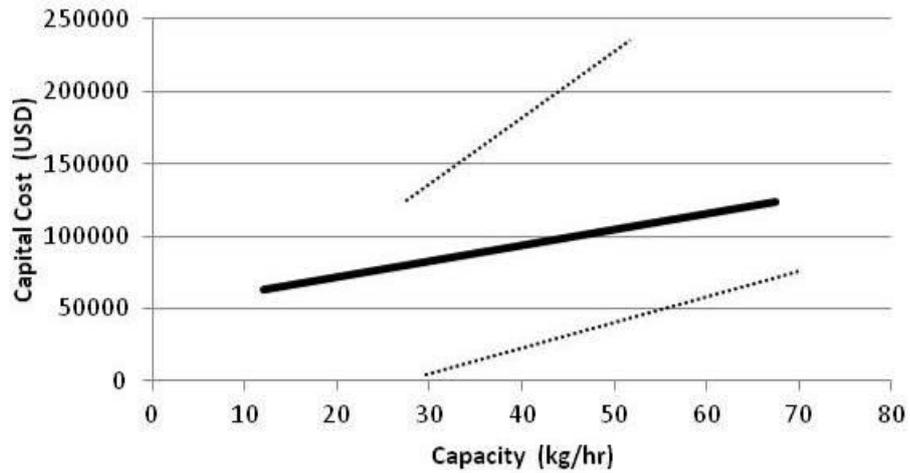


Figure 11.19. Cost of a Waste Treatment Autoclave with a Shredder or Compactor (Capacity > 100 kg/hr)

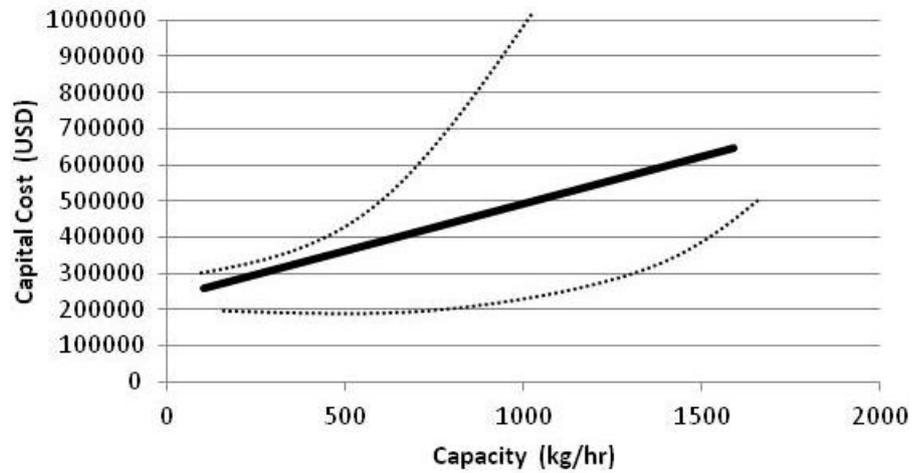


Figure 11.20. Cost of a Hybrid Waste Treatment Autoclave

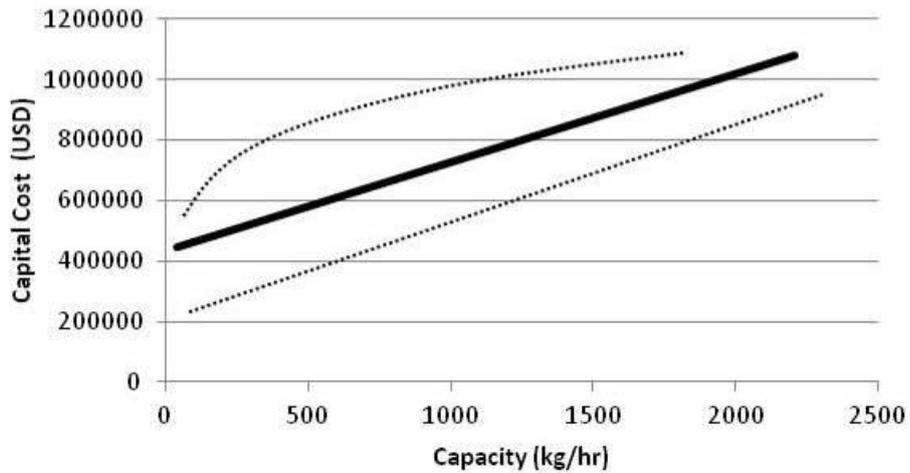


Figure 11.21. Cost of a Hybrid Waste Treatment Autoclave

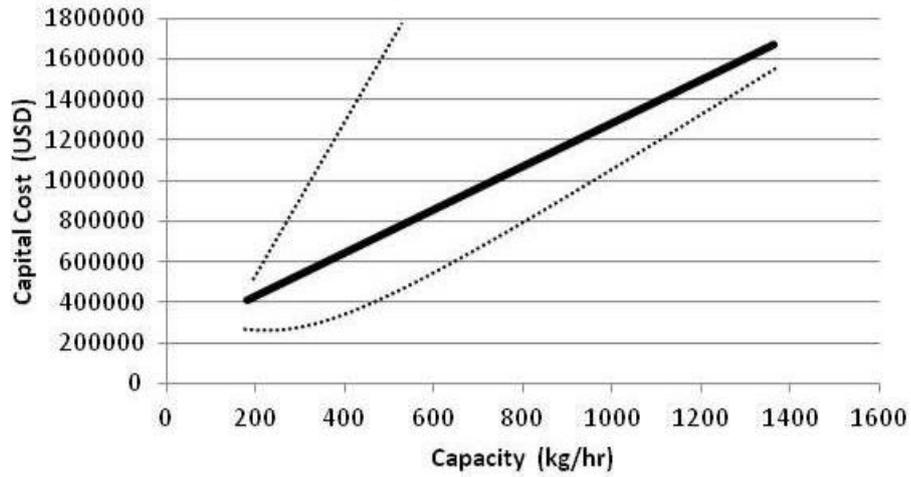


Figure 11.22. Cost of a Batch Microwave Unit

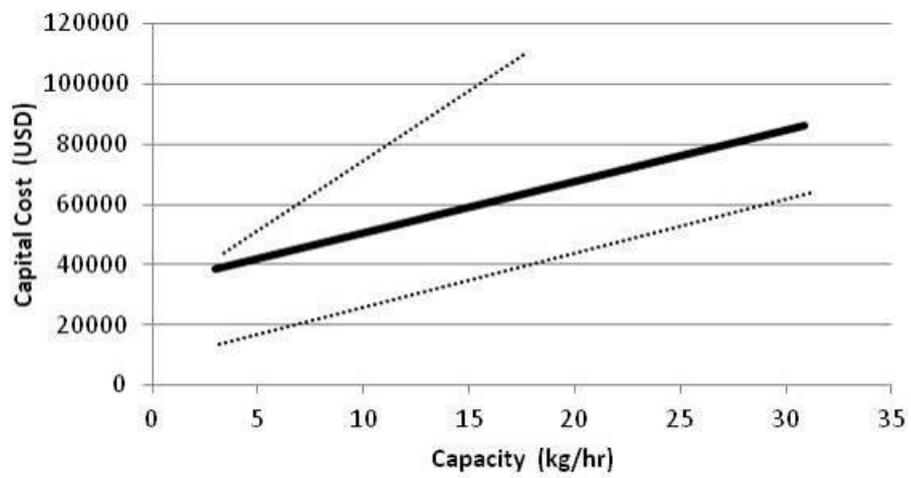


Figure 11.23. Cost of a Continuous Microwave Unit

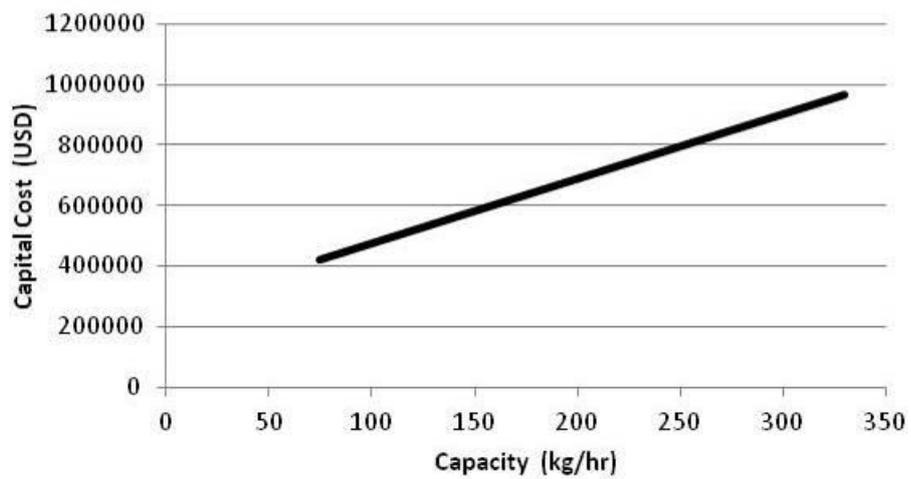


Figure 11.24. Cost of an Incinerator with Air Pollution Control that Meet International Standards

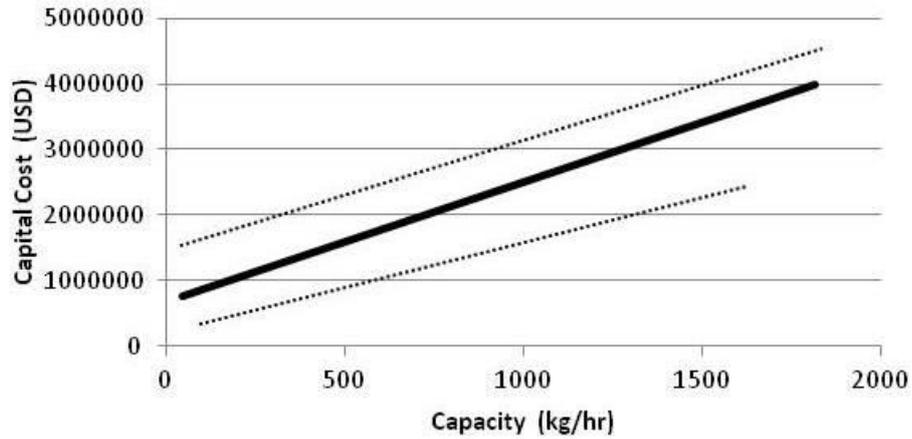


Figure 11.25. Cost of a High Pressure Alkaline Hydrolysis Unit

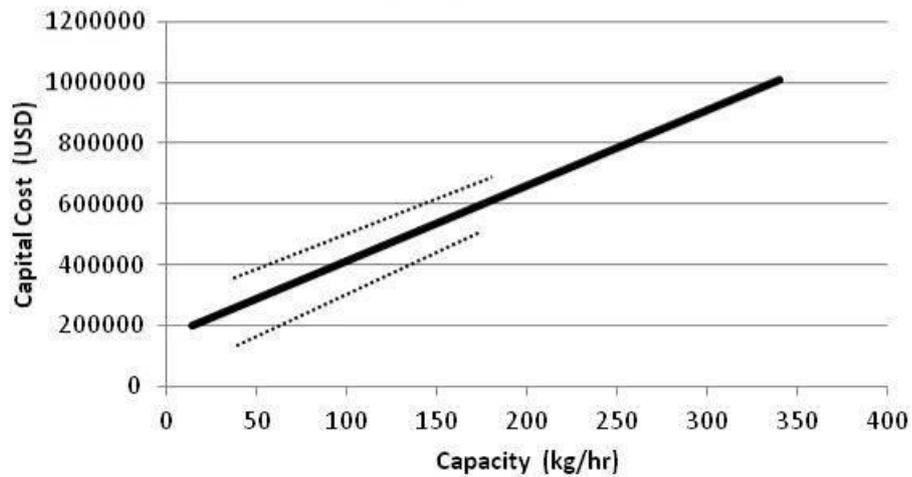
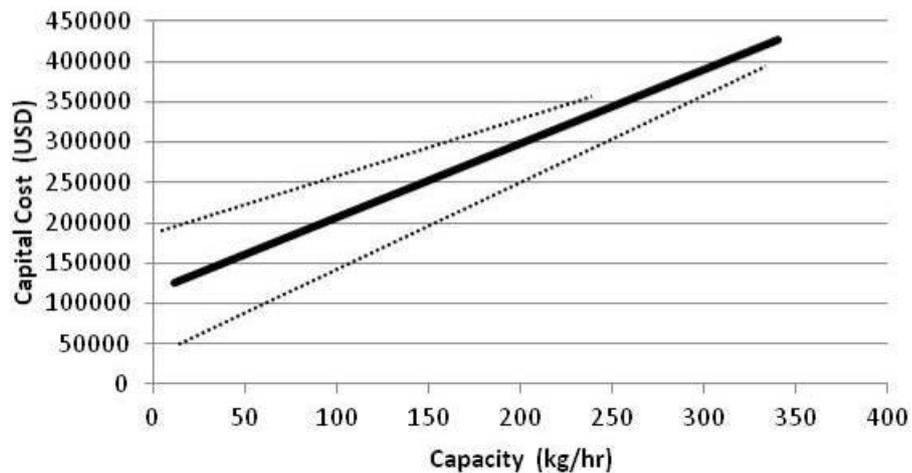


Figure 11.26. Cost of a Low Pressure Alkaline Hydrolysis Unit



A small, table-top dry heat technology capable of treating 3.8 liters in 2.5 hours costs about USD 7000. For frictional heating treatment systems, a unit with a capacity of 25 or 30 kg/hr costs between USD 110,000 to 160,000.

Table 11.6 gives the range of operating costs for each category of technology.

Table 11.5. Operating Cost Items<sup>184,185,186</sup>

Technology	Range of Capacities (kg/hr)	Range of Operating Costs (USD/kg)
Autoclave	2 to 3600	0.14 to 0.33
Hybrid autoclave	18 to 2200	0.05 to 0.12
Continuous steam treatment	100 to 1800	about 0.15
Batch microwave unit	1.5 to 31	about 0.13
Continuous microwave unit	100 to 810	0.07 to 0.11
Frictional heating	10 to 1500	>0.13
Incinerator with air pollution control	5 to 3500	0.27 to 1.66
Alkaline hydrolysis	7 to 4500 kg per cycle	0.10 – 0.19
Chemical treatment	23 to 410	0.12 to 0.52

#### 11.5.4 INSTITUTIONAL AND REGULATORY REQUIREMENTS

A healthcare waste management system should be viewed as the integration of best management practices and best environmental technologies. As such, the institutional requirements involve those related to best practices that have an indirect impact on the technology and its sustainability, as well as requirements specific to the type of technology selected.

The principal institutional requirements that indirectly affect the technology include:

- Promulgation of facility policies dealing with healthcare waste management and clearly delineating roles and responsibilities
- Commitment by the facility management to healthcare waste management
- Detailed facility guidelines, plans and procedures dealing with healthcare waste management practices, including waste classification, waste minimization, segregation, container specifications, color coding, labeling, collection, handling, transport, storage, contingency plans, and final disposal
- Financing of healthcare waste management, including costs of waste bags, containers, carts, posters, personal protective equipments, cleaning materials, refresher training, etc.
- Initial and periodic training on healthcare waste management
- Continuous monitoring, evaluation and improvement of waste management practices
- Active healthcare waste management organization linked with infection control, occupational safety and quality committees.

For example, the lack of waste minimization could result in exceeding the capacity of the treatment technology. Poor segregation, ineffective training, or lack of waste bags could harm the treatment technology operators, for example, when sharps are not placed in puncture-proof containers. Improper segregation could also damage the technology, such as discarding hard prosthetic metal in technologies that use internal shredding.

Other institutional requirements have a direct impact on the technology. These include:

<sup>184</sup> Data for chemical treatment from: L.F. Diaz and G.M. Savage (2003). "Risks and Costs Associated With the Management of Infectious Wastes." WHO/WPRO, December 2003.

<sup>185</sup> Data for autoclaves, hybrid autoclaves, continuous steam, and continuous microwave from: J. Emmanuel, "New and Emerging Technologies for Medical Waste Treatment," CR-107836-R1, EPRI Health Care Initiative, Palo Alto, CA, January 1999; for batch microwave and frictional heating: data provided to J. Emmanuel in 2011 and data on certified technologies in Poland; for data on alkaline hydrolysis: J. Emmanuel, J.H. Keene, and R. Trower, "Evaluation of Alkaline Hydrolysis Digestion Technology for Decontamination and Disposal of Potentially Infectious Animal Carcasses," CRC Report prepared for the U.S. National Institutes of Health, Council Rock Consulting, Rio Rancho, NM, January 18, 2005.

<sup>186</sup> Data for incinerators calculated from: T. Holloway, "Baseline Operating Costs for Existing HMIWI," Memo to the U.S. Environmental Protection Agency, RTI Project No. 0210426.002.003, RTI International, Research Triangle Park, NC, October 24, 2008.

- General policies regarding treatment of healthcare waste
- Detailed guidelines and procedures regarding operation and preventive maintenance of the treatment technology
- Budget allocation for treatment technology operation including costs of labor, personal protection equipment, cleaning supplies, electricity, fuel, water, sewage, collection of treated waste, landfill tipping fees, etc.
- Annual budget to cover the costs of periodic maintenance and repairs
- Procedures for periodic testing and validation of the technology (e.g., periodic microbial inactivation tests for autoclaves and other low-heat thermal technologies, periodic air emission stack tests of incinerators)
- Updates of registrations, permits, licenses and other regulatory requirements related to the treatment system and operation
- Supervision and monitoring of treatment technology operators
- Initial and periodic refresher training of treatment technology operators.

The ultimate failure of treatment technologies, regardless of the type of technology used, is often the result of a lack of commitment to the operation and maintenance of the technology. This is reflected in the absence or insufficiency of the operating and maintenance budget. Little or no preventive maintenance means frequent breakdowns and a shorter equipment life span. In the end, the equipment is left in a state of disrepair, with no budget for repair or spare parts.

Regulatory requirements depend on the legal framework and regulatory infrastructure of each country. Requirements indirectly affecting the treatment technologies include hospital licensing and accreditation (which may entail submission of healthcare waste management plans and procedures), license renewals of healthcare professionals (which may include proof of training in healthcare waste management), and certification of healthcare waste managers.

Regulations that are directly related to the treatment technology include registration as a healthcare waste generator by the Ministry of Environment, approval to transport untreated waste to a central treatment facility, or approval to treat the waste in the facility's premises. In the case of on-site treatment, the license or permit usually specifies the type of technology, range of operating conditions, environmental emission limits and duration that the facility is allowed to operate the technology. Licenses or approvals may also be granted dealing with collection and transport, especially for central treatment facilities. Other requirements are specific to the technology used.

For low-heat thermal technologies, the main regulatory requirement is usually the pre-approval of the technology and record-keeping or documentation of treatment. The Ministry of Health may require submission of treatment documentation (such as treatment logs showing the color-changing indicators and results of microbiological testing) every quarter or every year. In developing countries where the new state-of-the-art technologies—such as hybrid autoclaves, continuous steam treatment and microwave units—are not known or well established, there may need to be prior approvals from the Ministries of Health, Environment and/or Science & Technology for use in the country. Since the air emissions from the low-heat technologies are minimal, the Ministry of Environment's concerns are usually limited to the disposal of treated waste, which is considered the equivalent of regular domestic waste. Local authorities may be involved in the wastewater discharge, which is generally not an issue, as well as in landfill disposal. Health inspectors may assess waste storage, separation of untreated and treated waste, use of personal protection equipment and the general cleanliness of the treatment facility.

For high-heat technologies such as incineration, the Ministry of Environment and local authorities regulate air emissions and generally require periodic stack tests of particulate matter (dust), carbon monoxide, HCl, NO<sub>x</sub>, SO<sub>x</sub>, total organic carbon, and various metals such as lead, mercury and cadmium. In other countries, tests of dioxins and furans are also required every year or so in keeping with international test protocols and standards. Dioxin tests are difficult and expensive and can be done only in a limited number of accredited laboratories around the world. The Ministry of Environment also regulates the disposal of incinerator ash in hazardous waste landfills. For incinerators that use wet scrubbers and quenchers, the Ministry of Environment and local

authorities regulate effluent discharges. Health inspectors may assess waste storage, separation of untreated and treated waste, use of personal protection equipment, handling of the incinerator ash, and the general cleanliness of the treatment facility.

For the chemical treatment systems, the Ministry of Environment regulates the storage, use and disposal of chemicals, as well as the wastewater discharge. Test of the wastewater may be required prior to approval. Periodic effluent tests may be a condition for regular operation. The Ministry of Health may require submission of documentation (results of microbiological tests, treatment logs showing operating parameters) every quarter or every year as proof of the efficacy of pathogen destruction. Health inspectors may assess chemical storage, waste storage, separation of untreated and treated waste, use of personal protection equipment, ambient indoor air quality, chemical exposure and the general cleanliness of the treatment facility.

Table 11.6 gives a qualitative comparison of the institutional and regulatory requirements for different technologies. Institutional requirements are based primarily on the extent of operating and preventive maintenance needs, the likelihood and costs of repairs, and costs of periodic testing. The regulatory requirements based on the degree of environmental regulations associated with the different types of technologies.

Table 11.6. Institutional and Regulatory Requirements of Treatment Technologies

Technology	Institutional Requirements		Regulatory Requirements	
		Notes		Notes
Autoclaves	X		X	
Hybrid autoclaves	X X	(1)	X	
Continuous steam treatment systems	X X	(1)	X	
Batch microwave technologies	X		X	
Continuous microwave technologies	X X	(1)	X	
Frictional heat treatment systems	X X	(1)	X	
Dry heat treatment systems	X		X	
Incinerators	X X X	(2)	X X X	Air emission testing and hazardous ash disposal
Alkaline hydrolysis technologies	X X	(1)	X	
Chemical treatment systems	X X	(1)	X X	Chemical storage, disposal and residues

Legend: X – few basic requirements, X X - some requirements, X X X - many requirements; (1) maintenance and repair of moving parts; (2) maintenance and repair of parts exposed to high temperatures and thermal stresses (e.g., refractories), corrosive gases, fly ash and dust, as well as maintenance and repair of moving parts especially in the flue gas cleaning system

#### 11.5.5 SUMMARY OF PROS AND CONS FOR DEVELOPING COUNTRIES

Table 11.6 presents important technical comparisons between the different generic technologies based on the descriptions given above. ‘+’ signifies a comparative advantage or benefit while ‘-’ signifies a relative disadvantage.

Table 11.6. Summary of Technical Comparisons of Treatment Technologies

	1	2	3	4	5	6	7	8	9	10
Range of capacities	+++	++	++	+	++	+	-	++	+	++
Range of waste treated	+	++	++	+	++	++	-	+++	-	+
Efficacy of microbial inactivation	++	++	+	+	+	++	+	+++	+++	++
Volume reduction	+	++	++	+	++	++	++	+++	+++	++
Mass reduction	-	+	+	-	-	+	+	++	+++	-
Space needed for installation	++	+	+	+++	+	+	+++	-	+	+
Installation requirements	++	+	+	+++	+	+	+++	-	+	+
Degree of automation	+	++	++	+++	++	++	+++	++	++	++

Legend: 1 – Autoclaves; 2 - Hybrid autoclaves; 3 - Continuous steam treatment systems; 4 - Batch microwave technologies; 5 - Continuous microwave technologies; 6 - Frictional heat treatment systems; 7 - Dry heat treatment systems; 8 – Incinerators; 9 - Alkaline hydrolysis technologies; 10 - Chemical treatment systems.

Table 11.7 summarized the qualitative comparisons between the different generic technologies of the specific considerations pertinent to developing countries. This table is intended as a rough comparison but each specific technology should be evaluated based on its particular merits.

Table 11.7. Qualitative Comparison Summary of Treatment Technologies

	1	2	3	4	5	6	7	8	9	10
Environment	+	+	++	++	++	++	++	--	-	-
Occupational safety	-	-	++	++	++	++	++	--	-	--
Job creation (based on equipment size)	+++	+++	+++	+	+++	++	+	+++	++	++
Social acceptance	+	+	+	+	+	+	+	--	-	-
Capital cost (per tonne of waste)										
Operating cost (per tonne of waste)										
Institutional requirements	+++	++	++	+++	++	++	+++	+	++	++
Regulatory requirements	+++	+++	+++	+++	+++	+++	+++	+	+++	++

Legend: 1 – Autoclaves; 2 - Hybrid autoclaves; 3 - Continuous steam treatment systems; 4 - Batch microwave technologies; 5 - Continuous microwave technologies; 6 - Frictional heat treatment systems; 7 - Dry heat treatment systems; 8 – Incinerators; 9 - Alkaline hydrolysis technologies; 10 - Chemical treatment systems.

## 11.6 EXAMPLES OF SPECIFIC APPLICATIONS

### 11.6.1 SMALL AUTOCLAVE-SHREDDER FOR A DISTRICT HOSPITAL<sup>187</sup>

The Bagamoyo District Hospital, one of 229 similar hospitals in Tanzania, is a 125-bed general hospital with 5 wards (maternity, female ward, male ward, pediatrics, and isolation ward) with an occupancy rate of around 100%. The hospital also has two operating theaters, dental surgery, eye department, and various outpatient departments. There is a staff of 183 personnel including 72 non-medical attendants. It is also the home for a research center on malaria. The hospital’s DeMontfort incinerator had broken down after about a year and the local community had complained about the smoke from the incinerator causing respiratory problems among the children.

A baseline assessment was conducted to determine the amounts of waste generated. Training was provided to improve segregation practices. Color-coded bins, bags, personal protection equipment, and segregation posters were given to the hospital. A new treatment building was constructed and the incinerator was replaced with a 167-liter stainless steel ACMAS autoclave and PIMCO plastic shredder with rotating blades. The equipment was imported from India. The shredder was used primarily to shred treated needles and syringes. Microbial inactivation efficacy tests were conducted to establish the operating parameters for the autoclave. The equipment has been in operation since October 2008.



<sup>187</sup> R. Stringer, J. Kiama, J. Emmanuel, E. Chenya, J. Katima and F. Magoma, “Non-Incineration Medical Waste Treatment Pilot Project at Bagamoyo District Hospital, Tanzania,” Joint report by Health Care Without Harm, UNDP GEF Global Healthcare Waste Project, AGENDA, John Snow Inc. and Making Medical Injections Safer, September 2010.

*Figure 11.16. Vertical autoclave (L), shredder (M) and housing (R) at Bagamoyo Hospital, Tanzania*



*Figure 11.17. Sharps waste before (L) and after (R) treatment and shredding*

#### 11.6.2 AUTOCLAVE-SHREDDER AT A CENTRAL TREATMENT FACILITY<sup>188</sup>

GJ Multiclave is a central treatment facility in Kancheepuram District in the state of Tamil Nadu in India. The facility collects and treats waste from more than 375 healthcare facilities in the region, totaling about 4 tons of waste per day. Under Indian rules, some portion of the waste is incinerated and the rest, including sharps waste, is treated in one of two autoclaves and a shredder. The gravity-displacement autoclaves and shredder are a locally manufactured.



*Figure 11.18. Autoclave (L) and shredder (L) at the GJ Multiclave Central Treatment Facility, India*

#### 11.6.3 LARGE AUTOCLAVE AT A CENTRAL TREATMENT FACILITY<sup>189</sup>

Compass Waste Services in Durban, South Africa, collects and treats healthcare waste and sharps waste from facilities throughout the region. The facility uses two large-scale Bondtech vacuum autoclaves (1.26 m diameter x 6 m long each) with a capacity of treating about 1 tonne of waste every 72 minutes. The plant treats a total of 14 tonnes of waste every 12 hours. As of 2007, there had been no failures of the microbial tests. The plant also uses a two-shaft ShredTech shredder and a Daniels System robotic sharps treatment system for reusable sharps containers.

<sup>188</sup> Information provided to the author in July 2010 by Sanjay Kumar, GJ Multiclave, Tamil Nadu, India.

<sup>189</sup> Information provided to the author in October 2007 by Nicole Pahl and Michael Smith, Compass Waste Services, Durban, South Africa.



Figure 11.19. Large vacuum autoclaves (L) and shredder (R) at the Compass plant in South Africa

#### 11.6.4 HYBRID AUTOCLAVE AT AN URBAN HOSPITAL AND OTHER HOSPITALS<sup>190</sup>

The Tata Memorial Hospital is a leading specialist cancer treatment and research centre in Mumbai, India. The hospital treats about 43,000 new patients every year with over 1,000 patients attended to by the outpatient department every day. Nearly 6,300 major operations are performed annually and 6,000 patients are treated with radiotherapy and chemotherapy each year. In the 1990s, the average waste generation was 5,370 kg of infectious waste per year. In September 1999, the hospital installed a Model H-25 Hydroclave (hybrid autoclave with rotating fragmenting arm). Microbiological tests using *Geobacillus stearothermophilus* showed destruction of the bacterial spores in all of the tests conducted for a whole year (50 tests) in 1999 to 2000.



Figure 11.20. Hydroclave, conveyor and shredder at Tata Memorial Hospital, India

The Hydroclave company has also installed six H-25 Hydroclaves and 8 H-15 Hydroclaves in various hospitals in Niger for in-hospital treatment.



Figure 11.21. Hydroclave H-25 (L) and H-15 (R) similar to the 14 units installed at hospitals in Niger

#### 11.6.5 HYBRID VERTICAL AUTOCLAVE AT A LARGE URBAN HOSPITAL<sup>191</sup>

The non-governmental organization Arcenciel operates the treatment facility at the 400-bed Hotel Dieu Hospital in Beirut, Lebanon. Treatment is done with an Ecodas T-300 (capacity of 60 kg/hr) treating about 580

<sup>190</sup> Information provided to the author in February 2003 by Dr. Rohini Kelkar, Tata Memorial Hospital, Mumbai, India.

<sup>191</sup> Information provided to the author in August 2010 by Dany Obeid, Roland Korkomas and Dr. Dominique Solameh of Arcenciel, Beirut, Lebanon.

kg per day of infectious waste from Hotel Dieu Hospital and other surrounding health facilities. Arcenciel operates 5 healthcare waste treatment centers in different parts of the country processing about 5 tons per day using the Ecodas and Hydroclave systems. Waste is weighed at the hospitals during pick-up, reweighed at the treatment centers, and the treatment documentation is submitted to the Ministry of Environment every quarter.



*Figure 11.22. Ecodas T300 at Hotel Dieu Hospital, Lebanon*

#### 11.6.6 CONTINUOUS STEAM TREATMENT AT A TERTIARY URBAN HOSPITAL<sup>192</sup>

Virginia Hospital Center is a state-of-the-art 334-bed tertiary hospital in Arlington, Virginia, USA. It is a teaching hospital and a comprehensive healthcare center providing services in cardiology, cardiovascular surgery, oncology, neuroscience, urology, women and infant health, lung cancer, colorectal surgery and other fields. The hospital installed a highly automated STI ChemClav continuous steam treatment system for its infectious waste. Waste bins are fed in batches but the system operates continuously with minimal odors. The treated residue is a relatively dry, finely shredded waste thereby achieving high volume reduction.



*Figure 11.23. STI ChemClav (L), automatic waste dumper (M), and close-up of treated/shredded waste (R) at the Virginia Hospital Center, USA*

#### 11.6.7 ROTATING AUTOCLAVE AT A CENTRAL TREATMENT PLANT AND A BATCH MICROWAVE AT A HOSPITAL<sup>193</sup>

The Lautus central treatment plant just outside Riga, Latvia, collects and treats healthcare waste from around the country. Waste bags are brought in by trucks and placed in 660-liter red carts which are then fed automatically to the treatment unit using an automatic bin dumper. Lautus uses a Tempico Rotoclave 1250 (5.8 m diameter x 9.1 m long rotating autoclave with internal vanes). The rotation of the inner drum breaks open the bags against the vanes allowing pressurized steam to penetrate the waste. The treated waste is transported to a heavy-duty Vecoplan shredder via conveyor belts. The shredded waste is then moved through a second series of conveyor belts to a compactor and roll-off container which is then taken to the landfill.

<sup>192</sup> J. Emmanuel, J.H. Keene, R. Trower, J. Osorio and K.C. Simons, "Medical Pathological Waste Report," report prepared for the U.S. National Institutes of Health, CRC, Rio Rancho, NM, 2006.

<sup>193</sup> Information provided to the author in December 2009 by Egija Siliniece and Inese Akeldama-Krūmiņa, Ventspils Hospital, Latvia; and in September 2008 and July 2011 by Dr. Sandra Eglite, LAUTUS SIA, Riga, Latvia.



*Figure 11.24. (L-R) Automatic bin dumper (L), control panel, Tempico Rotoclave and close-up of treated/shredded waste (R) at the Lautus Central Treatment Plant, Latvia*

The Municipal Hospital of Ventspils in Latvia is a 241-bed public hospital in the western part of the country. The hospital uses a Medister 160 batch microwave unit (capacity of 60 liters per batch). Waste in the hospital is collected in 60 liter Meditainer waste containers which are on a pedal-operated stand. The Medister is an automated front-loading system with an average treatment cycle time of 45 minutes.



*Figure 11.25. METEKA Medister (L) and Meditainer containers (M) at the Ventspils Hospital, Latvia, and METEKA photo of the pedal-operated stand and transport trolley*

#### 11.6.8 CONTINUOUS MICROWAVE UNIT AT A CENTRAL TREATMENT PLANT<sup>194</sup>

Chevalier Enviro Services, Inc. (CESI) a central storage, treatment and disposal facility located in an industrial area in Paranaque, Philippines. It serves about 200 hospitals and clinics in Metro Manila (about 60-70% of all Metro Manila hospitals) and in three nearby provinces. CESI provides containers and bags, collects waste in their transport vehicles, weighs the waste and treats the waste at their central facility. They operate a Sanitec microwave unit (capacity of 250-400 kg/hour depending on waste densities). Waste bins are fed intermittently into the hopper. After the waste goes through the internal shredder, it is transported up an inclined auger for continuous exposure to microwave energy and steam. The treated waste is then sent to a landfill.



*Figure 11.26. Sanitec microwave cut-out sketch and photo similar to the unit in CESI, Philippines*

<sup>194</sup> Information provided to the author in August 2010 by Victoriano A. Andutan Jr. and Sharon Igalada of CESI, Philippines.

#### 11.6.9 FRICTIONAL HEAT TREATMENT UNIT AT A HOSPITAL<sup>195</sup>

Bolak El Dakroor General Hospital in Giza, Egypt installed the Newster 10 frictional heat treatment system in July 2010. The technology treats about 30 kg per hour.



Figure 11.27. Newster 10 (L) and close-up of treated waste (R); similar to the unit installed in Bolak El Dakroor Hospital, Egypt

#### 11.6.10 HIGH-TECH INCINERATOR AT A CENTRAL TREATMENT PLANT<sup>196</sup>

The famous Spittelau incinerator in Vienna, Austria has a capacity of about 260,000 tons per year. The plant continuously measures particulate matter (dust), HCl, SO<sub>2</sub>, NO<sub>x</sub>, CO, hydrocarbons, and NH<sub>3</sub>. Polychlorinated dioxins and furans are analyzed monthly while heavy metals and HF are analyzed every year. Test results are sent on-line to the regulatory authority and made public. The incinerator produces 230 kg of slag per tonne of waste and 19 kg of filter ash per tonne of waste. (At very high incinerator temperatures, the bottom ash in the incinerator fuses into a vitreous slag.) Both the slag and filter ash are mixed with cement and used for landfill construction.

For flue gas cleaning, the Spittelau incinerator uses an electrostatic precipitator for dust reduction; a two-stage scrubber for reduction of SO<sub>2</sub>, HCl, and HF; a fine dust separator; and a selective catalytic reactor-DeNO<sub>x</sub> facility to reduce NO<sub>x</sub>. Heavy metals removed by the first scrubber are treated with lime slurry as well as special precipitation and flocculating agents, after which the insoluble metals are filtered. The incinerator stack emits 0.8-2 mg/m<sup>3</sup> of dust with a dioxin/furan concentration of about 0.03 ng I-TEF/m<sup>3</sup>. About 1.1 kg of sludge cake per tonne of waste are produced from wastewater treatment; the cake is buried as hazardous waste in a salt mine.

There are about 80 highly trained personnel employed by the plant. Along with the incinerator, the city promotes recycling programs such that about 38% of Vienna's waste is recycled. The Spittelau plant is a tourist spot and is known for its colorful façade designed by the famous architect and artist Friedensreich Hundertwasser.



Figure 11.28. Views of the Spittelau waste incinerator, Austria

<sup>195</sup> Information provided to the author in May 2011 by Beatrice Giordani of Newster Srl, Italy.

<sup>196</sup> Herwig Schuster, "Waste Incineration Plants in Austria with data on waste management in Vienna," Greenpeace, Vienna, Austria, June 1999.

#### 11.6.11 ALKALINE HYDROLYSIS TECHNOLOGY AT A VETERINARY LAB<sup>197</sup>

The Backweston Veterinary Laboratory near Dublin, Ireland is an arm of the Department of Agriculture, Fisheries and Food. The Laboratory installed a BioSafe Engineering WR<sup>2</sup> alkaline digester on May 2005. The unit is able to destroy contaminated animal carcasses and waste.



*Figure 11.29. WR<sup>2</sup> alkaline hydrolysis unit and close-up of bone residues; similar to the unit installed at the Backweston Veterinary Lab, Ireland*

---

<sup>197</sup> Information provided to the author in September 2010 by Randall McKee, BioSafe Engineering, Brownsburg, Indiana, USA.

## IV. SPECIFIC TECHNOLOGIES

---

### 12 SPECIFIC TECHNOLOGIES FOR HEALTHCARE WASTE TREATMENT

---

#### 12.1 AUTOCLAVES

##### 12.1.1 AWS CLINICAL WASTE

###### **Type of Technology**

Autoclave

###### **Process Description**

The AWS System is a horizontal autoclave sterilizer which could be a stand-alone unit or integrated into a fully automated system including a large storage hopper and automatic waste bin emptying and cleaning system. The fully automated system is made fully operational 24 hours a day by the company (except during maintenance and upgrading). See also Section 11.3.1.1.

###### **Types of Waste Treated**

The AWS System is used for healthcare waste (see Section 11.3.1.2) as well as for treating and destroying quarantine waste from international shipping and aviation at seaports and airports.

###### **Range of Capacities**

Model	Capacity	
	(liters/cycle)	(kg/cycle)*
MICRO STERILISER AWS11	20	2
MINI STERILISER AWS12	100	10
UNIVERSAL STERILISER AWS24	240	24
MIDI STERILISERS: AWS36 to AWS47	1000 to 2000	100 to 200
MAXI STERILISERS: AWS58 to AWS525	3000 to 10000	300 to 1000
INDUSTRIAL STERILISERS: AWS615 to AWS630	10000 to 20000	1000 to 2000

\* Basis: 100 kg/m<sup>3</sup>

###### **Pathogen Destruction**

See Section 11.3.1.4. The AWS System follows international standard protocols for verifying the effectiveness of the steam sterilization treatment process using biological challenge procedures (spore testing) and autonomous thermocouple testing (NATA certified thermal testing or equivalent).

###### **Emissions and By-Products**

The AWS system offers an “AWS No Emissions to Atmosphere” (NETA) system designed to condense emissions from the AWS sterilizer thereby eliminating all condensable odors. , approved by and in compliance with the most stringent Environmental Protection Agency Requirements. AWS offers the new NETA System as an upgrade to existing Systems to meet Environmental Protection Agency Requirements and to improve the workplace environment.

###### **Operation**

The sterilizer operates at 121°C but can be operated up to 145°C (see Section 11.3.1.6). It is highly automated and can be operated 24 hours a day without an operator.

###### **Installation**

The AWS system is skid mounted for easy installation.

###### **Maintenance**

See Section 11.3.1.8 for typical maintenance. Technical support can be provided by AWS onsite and via the Internet. The AWS System is fully supported by a comprehensive Technical Support Program which enables

AWS to monitor and enhance the performance of the AWS System via the Internet and through local representation providing periodic maintenance, inspections and tests.

### **Job Potential**

Operators are not required when the AWS System is part of the totally automated system, hence the job potential is low. The AWS System can also be run by an operator.

### **Locations where Technology is in Operation**

The AWS System has been sold in most Australian States, New Caledonia, Papua New Guinea, New Zealand, UK, India and the USA including sales to Government-constituted bodies. The company has representatives in Asia and the US.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

AWS offers the following special features: electronic waste tracking, bar code scanning, electronic weighing with software, integrated post-treatment shredding offered (no need for shredding when using AWS accessories and recycling treated waste), “No Emissions to Atmosphere” (NETA) System odor control, needle removal appliance, scalpel blade removal appliance, shrink wrap autoclavable bag, biological challenge kit (spore test kit), and AWS full Technical Support Program including online monitoring.

### **Parameters for Specification**

Model number (capacity), electrical specifications, supplied steam or steam generator, accessories and other features

### **Photographs**



L-R: Model AWS24, representative of Models AWS36 to 47, representative of Models AWS58 to 525

### **Vendor Information**

AWS Clinical Waste is an Australia-based company that has been installing quarantine waste treatment systems since 1989 and healthcare waste treatment systems since 1995.

### **Contact Information**

AWS Clinical Waste  
Suite 27, Cleveland House  
120 Bloomfield Street  
Cleveland Queensland 4163  
Australia  
Phone: +61 7 3821-1500  
Mobile: 0417 511 500  
Email: awsclinical1@bigpond.com  
Web: www.awsclinical.com

## 12.1.2 BONDTECH

### **Types of Technology**

Vacuum autoclave

### **Process Description**

Bondtech offers a high vacuum, horizontal, waste autoclave with hydraulic quick-opening breech lock type door with a safety interlock and locking ring, vacuum pump, temperature probes, programmable control system, recorders (to document date, time, pressure, and temperature), and a condenser to remove excess moisture. The pressure vessel meets ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. See also Section 11.3.1.1.

### **Types of Waste Treated**

See Section 11.3.1.2.

### **Range of Capacities**

Capacities of Bondtech autoclaves range from 90 kg to over 3200 kg/cycle (200 lbs to 7,000+ lbs/cycle).

### **Pathogen Destruction**

Tests conducted on both bagged and boxed medical wastes at sterilization rates in excess of 820 kilograms per hour (1800 pounds per hour) for each of two Bondtech autoclaves showed in excess of 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

The operation entails bin loading, closing the door, starting the automatic cycle (pre-vacuum, steam injection, steam exposure for a pre-determined time, and post-vacuum), unloading, and documentation. See Section 11.3.1.6.

### **Installation**

The Bondtech system is packaged & modularized for easy installation. The company provides a complete set of valves and piping, and external insulation. See also Section 11.3.1.7.

### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The Bondtech system requires an operator and is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

The Bondtech medical waste autoclaves have been installed in Argentina, Canada, Chile, Ireland, Mexico, Peru, Philippines, Puerto Rico, Qatar, South Korea, Thailand, most states of the US, and other countries.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Bondtech offers an internal track, steam ejector or liquid ring vacuum pump, steam condenser, and a loading ramp or lift table. Optional automatic loading systems, compactors, medical waste containers, conveyor systems, autoclavable bags, bin dumpers, balers, and low-speed high-torque waste shredders are also available.

### **Parameters for Specification**

Capacity (as estimated size and anticipated maximum load), temperature and pressure requirements, heating requirements (electrical, direct steam, indirect steam), type of control (push button, microprocessor, or computer), electrical specifications, accessories and other features

### **Photographs**



L-R: Bondtech autoclave, on-site autoclave with lift table at a hospital, waste dumper

**Vendor Information**

Bondtech Corporation is a US-based full service company designing, engineering and manufacturing autoclaves systems, along with material handling, for applications in various technical industries such as healthcare waste treatment, aerospace composites, glass lamination, rubber vulcanizing, wood treating, yarn setting and many other applications. The company has been making healthcare waste treatment autoclaves since 1983.

**Contact Information**

Bondtech Corporate Headquarters  
 1278 Highway 461  
 Somerset, Ky 42503  
 USA  
 Tel.: 1-800-414-4231 or +1 (606) 677-2616  
 Fax: +1 (606) 676-9157  
 Email: Elsa Brown - elsabrown@bondtech.net  
 Website: <http://www.bondtech.net/index.php4>, <http://www.bondtechcorporation.com/>

12.1.3 CISA

**Types of Technology**

Vacuum autoclave

**Process Description**

CISA uses a highly resistant stainless steel pressure vessel with a mirror finish. The single-door or double-door sterilizer operates at 134°C for solid infectious waste and 121°C for liquid waste. The system has microprocessor-based controls with a touch screen, multiple safety features, automatic drainage sterilization, and an energy saving standby mode. Shredding and compaction are integrated into the treatment system. The components are housed in a stainless steel shelter and can be used indoors, outdoors or in a mobile treatment unit.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Capacity (liters/cycle)	Capacity (kg/hr)
MWT 3290	103	10-15
MWT 4212	253	30-40
MWT 6412	557	60-80
MWT 1115D	1182	120-150
WISE 15 (automated)	145	-
WISE 40 (automated)	259	-
WISE 80 (automated)	556	-

**Pathogen Destruction**

CISA's WISE autoclaves achieve 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### Emissions and By-Products

See Section 11.3.1.5.

### Operation

Infectious waste is collected in special color-coded carts or stainless steel trolleys. These carts or trolleys are designed for use with the CISA system and are washed and disinfected in automated or manual systems. After the waste is loaded in the WISE autoclave through the sliding door, the operator selects from several treatment cycles depending on the types of waste (e.g., solid waste or liquid waste). The next phases of the operation (unloading, dumping, shredding and compaction) can be automated or done manually.

### Installation

See also Section 11.3.1.7.

### Maintenance

See Section 11.3.1.8.

### Job Potential

The CISA WISE system requires an operator and is highly automated. Job potential is low.

### Locations where Technology is in Operation

The CISA systems have been installed in many countries around the world.

### Cost Estimates

See Section 11.5.3.

### Special Features

CISA offers their special carts and trolleys, an Aquazero system that cuts water consumption by 90%, water treatment units, air compressors, refrigerated storage room, cart washing-disinfection system, transport vehicles, weighing scales, invoice service software, centralized monitoring by Ethernet link, and a service and maintenance program.

### Parameters for Specification

Capacity, electrical specifications, accessories and other features

### Photographs



L-R: WISE indoor system, CISE mobile treatment unit, multi-language touch screen

### Vendor Information

CISA S.p.A. has been producing sterilization systems for over 60 years. It has manufacturing facilities in Italy and in four continents. CISA has distributors and technical service centers in Amman (Jordan) for Middle East and Central Asia, Joinville (Brazil) for Brazil, Miami (USA) for Latin America, Rabat (Morocco) for Sub-Saharan Africa, Singapore for Asia, New Delhi for India, and the headquarters in Pomezia (Rome) for the rest of the world. In addition, CISA has offices in Colombia, France, Germany, Indonesia, Kazakhstan, Libya, Russia, Tunis, UK, and Venezuela.

### Contact Information

CISA S.p.A. Italy Headquarters  
Via Pontina Km 28  
00040 - Pomezia - Roma - Italia  
Tel: +39 06 9114371  
Fax +39 06 9107565  
Email: coordination.sales@cisagroup.it  
www.cisagroup.it

#### 12.1.4 GEF TECHNOLOGY

##### **Types of Technology**

Steam flushing autoclave

##### **Process Description**

The GEF technology is a simple, low-cost, horizontal autoclave system designed for developing countries. Steam is generated by a separate boiler which can be used with electricity, bottled gas, LPG or other fuel sources. The autoclave and boiler are mounted on a steel frame and the entire system can fit at the back of a pick-up truck. Although the autoclave is gravity-fed, the system uses steam flushing along with reusable (autoclavable) waste containers that open inside the autoclave and allow steam to penetrate the waste. Steam flushing removes the air and decontaminates it before being released. The reusable containers are placed on pedal-operated stands during use and do not need plastic bags. After sterilization, the waste is compacted or shredded depending on whether a sharps destroyer is used or not. If segregated at the point of generation, decontaminated glass, plastic and other materials can be recovered after treatment, crushed and then recycled.

##### **Types of Waste Treated**

See Section 11.3.1.2.

##### **Range of Capacities**

The GEF unit has a capacity of about 200 liters. Multiple units operated simultaneously can be used to achieve higher capacities. The system uses autoclavable metal containers with capacities of 10 and 35 liters when 3/4<sup>th</sup> full. Four 35 liter containers fit in the autoclave.

##### **Pathogen Destruction**

See Section 11.3.1.4. The GEF technology has been shown to achieve at least a 5 Log<sub>10</sub> reduction of *G. stearothermophilus*.

##### **Emissions and By-Products**

See Section 11.3.1.5.

##### **Operation**

The operator loads the autoclavable containers into the horizontal unit. A simple controller is used to maintain the proper temperature and pressure or the system can be operated manually. When the temperature reaches 121°C for the first time, steam is flushed for a short period and then the temperature is increased again and held at the required temperature for a set exposure time. The sterilized waste can then be dumped into a compactor-baler or into a shredder. For autoclavable sharps containers, a mechanical assembly is used to safely dump the sterilized sharps waste into the shredder hopper. The empty containers are rinsed and placed back in foot-operated stands. The autoclavable containers are permanently color-coded and marked with the biohazard symbol.

##### **Installation**

The GEF technology requires a water source and a closed drain for both condensate and steam flushing. The system can operate on electricity, bottled gas, LPG, or other local fuels.

##### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The system requires an operator and workers to load, unload, compact or shred waste. Job potential is medium.

### **Locations where Technology is in Operation**

The GEF technology has been used in Tanzania and is intended for use in Africa and in developing countries.

### **Cost Estimates**

See Section 11.5.3. The system was designed to cost about as much as an incinerator with no pollution control and of the same capacity.

### **Special Features**

The GEF system consists of the technology as well as a system of best environmental practices and procedures and tools to implement a comprehensive healthcare waste management system. The GEF technologies include the horizontal autoclave, boiler, autoclavable containers, pedal-operated stands, autoclavable sharps containers or mechanical sharps destroyer, compactor-baler, and a mechanical assembly for shredders to avoid manual handling of treated sharps. Facilities can use a combination of these technologies to meet their needs.

### **Parameters for Specification**

Capacity, fuel specifications for the steam generator (gas, oil, electric or solid fuel), electrical specifications, accessories.

### **Photographs**



L-R: Horizontal autoclave, autoclavable waste container, compactor-baler

### **Vendor Information**

The GEF technologies were developed under a project of the United Nations Development Program in cooperation with the World Health Organization and Health Care Without Harm, and funded by the Global Environment Facility. The technologies were designed and built at the University of Dar es Salaam in Tanzania under the guidance of a Global Project Team and an international advisory committee.

### **Contact Information**

UNDP GEF Project Technology  
c/o Prof. Jamidu Katima and Prof. Emrod Elisante  
University of Dar es Salaam  
P.O. Box 35131  
Dar es Salaam  
Tanzania  
Website: <http://www.gefmedwaste.com>

#### 12.1.5 GK MOSS

### **Types of Technology**

Vacuum autoclave

### **Process Description**

The GK Moss system is a high vacuum horizontal retort autoclave with an internal track, external insulation with an aluminum exterior wrap, and all required control valves and piping. The autoclave includes a quick-opening hydraulic door unit with locking ring, liquid ring vacuum pump designed for high vacuum, temperature probe located in the exit drain to ensure accurate temperature reading, and a condenser to remove excess moisture. The pressure vessel meets ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

### **Types of Waste Treated**

See Section 11.3.1.2.

### **Range of Capacities**

The GK Moss system is sized according to the number of carts that can fit in the autoclave. They manufacture autoclaves capable of treating 1 to 6 carts, with each cart holding approximately 1.91 m<sup>3</sup> or 67.5 ft<sup>3</sup> corresponding to 136-158.75 kilograms/cart (300-350 lbs/cart). Thus, the GK Moss autoclave capacities range from 136 to 952 kg per cycle.

### **Pathogen Destruction**

See Section 11.3.1.4. Moss autoclaves have met all US state requirements for treatment of medical waste.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

The operator simply loads the waste bags from onto the cart tipper with spill chute. This device dumps the bags into the stainless steel autoclave carts. Each cart is then pushed into the autoclave from a cart lift table or up a ramp for processing. Once processed, the carts are removed from the autoclave and are rolled directly to the compactor/container or shredder cart dumper.

### **Installation**

The GK Moss system is modular and packaged for easy installation.

### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The GK Moss system requires an operator and is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

The Moss autoclaves are in operation in various states in the US with a large system being installed in Vietnam.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Moss autoclave is controlled by a PLC control system with a touch screen display located on the door panel. The display shows sterilizer status, time of day, cycle times, temperature and pressure readings and any warnings or alarms. The system also provides message readouts on the display screen and can communicate with a remote computer and send any alarm code to a pager, so that immediate attention can be given to the problem. Optional features include shredders (single, dual and four shaft designs), boiler systems and accessories, cart tippers, cart dumpers and compactor containers.

### **Parameters for Specification**

Capacity (based on number of carts), fuel specifications for the steam generator (gas, oil, electric or solid fuel), electrical specifications, accessories and optional features.

### **Photographs**



L-R: Moss autoclave (side view), autoclave with a waste cart inside, stainless steel waste cart

**Vendor Information**

The company has been making healthcare waste treatment autoclaves since 1982. In 1996, STERIS Corporation (formerly AMSCO) assigned Moss to be the AMSCO Eagleguard retort exclusive national distributor. Moss now offers the same basic retort type autoclave but with an enhanced user friendly/remote monitoring PLC control system, shredders, cart tipplers, cart dumpers, compactor/containers, Toter carts, stainless steel autoclave carts with complete system installations.

**Contact Information**

George K. Moss Co., Inc.  
 P.O. Box 380156  
 Birmingham, AL 35238  
 United States  
 Telephone: 205.408.2929  
 Toll Free: 800.759.MOSS (6677)  
 Fax: 205.408.4337  
 Email: steam@gkmoss.com  
 Website: <http://www.gkmoss.com/index.php/page/medicalwaste>

12.1.6 INCOL

**Types of Technology**

Vacuum autoclave

**Process Description**

The Incol autoclave is a horizontal multiple vacuum autoclave made of carbon steel with a vacuum system, safety valve, and a logic controller or computer to control temperature, pressure, exposure type and processing cycles. Sound and visual alarms notify the operator of problems. The autoclave can operate up to 180°C. The system is designed for loading stainless steel carts containing waste. The pressure vessel is built in accordance with the ASME Section VIII Code.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Number of Carts	Load per cart (kg)	Capacity	
			Kg/cycle	Kg/hr
SA-U 150	2	62	125	150
SA-U 240 PSI	2	100	200	240
SA-U 480	4	100	400	480
SA-U 600	5	100	500	600
SA-U 720	4	150	600	720
SA-U 1080	5	180	900	1080
SA-U 1200	4	250	1000	1200
SA-U 1500	5	250	1200	1500

### **Pathogen Destruction**

See Section 11.3.1.4.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

The standard model includes a steam generator to provide steam at a maximum pressure of 40 psi and temperatures of about 131 to 145 °C. The sterilization process is started by pushing the “Start Cycle Button” which begins the vacuum system and injection of steam. The sterilization cycle uses between one and three vacuum/steam injection pulses. The air extracted during the vacuum cycle passes through a secondary sterilization process to prevent release of any pathogens. The control system monitors the operating parameters, functions, sensors that control movement, and safety features until the end of the process, which ends with the drying and cooling phase. A lift table is used for moving carts in and out of the autoclave.

### **Installation**

See Section 11.3.1.7.

### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The Incol system requires an operator and is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

Incol has installed autoclaves throughout Argentina and Brazil.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Optional features include computerized system, carts, shredders and lined carts.

### **Parameters for Specification**

Model or capacity based on the number of carts, fuel specifications for the steam generator, electrical specifications, accessories and optional features.

### **Photographs**



L-R: Incol autoclave showing lift table and cart, autoclave with door closed, control panel

### **Vendor information**

INCOL S.A. is a private company that began in the early 1990s. It has offices in Argentina and Brazil.

### **Contact Information**

Incol Co SA.  
Chacabuco 4875, 1650, San Martin

Gran Buenos Aires  
 Argentina  
 Tel.: (54 11) 4768 7088 (Rot)  
 Fax: (54 11) 4767 6807  
 Email. info@incol.net  
 http://www.incol.net/

12.1.7 MACHINFABRIK

**Types of Technology**

Vacuum autoclave

**Process Description**

MachinFabrik manufactures high vacuum autoclaves that automatically tilt in different positions to aid in loading or unloading of waste. The autoclaves are designed with special doors, computer control, and automatic pressure relief devices and alarms. The system prevents waste from being discharged unless the required vacuum, pressure, temperature and time have been achieved. The MachinFabrik system uses devices for treating the condensate and decontaminating the air drawn out of the chamber during the pre-vacuum stage. The controls have a user friendly communication interface that keeps the operator informed what the machine is doing at any point during its operation. A strip chart printer documents the key process parameters (time, temperature, pressure and vacuum) for every sterilization process. MachinFabrik also offers semi-automatic and manually operated autoclaves as options.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Volume (liters)	Capacity (kg per cycle)
HAZCLAVE MINI	20	1
	35	3
	75	7
HAZCLAVE MEGA	180	12
	350	20
	450	45
	650	65
	900	90
	1200	110

**Pathogen Destruction**

See Section 11.3.1.4. These autoclaves have been tested using *Geobacillus stearothermophilus*.

**Emissions and By-Products**

See Section 11.3.1.5.

**Operation**

With the autoclave in loading position, the bags are loaded manually or automatically into the chamber. The doors are then shut and the sterilization cycle is initiated. The first phase of the process is a steam-vacuum pulsing to ensure total air removal and effective penetration of steam. Steam is subsequently injected to raise the temperature of the load to 139°C. After the sterilization phase the steam is vented out and the steam is passed through a condenser where it is condensed to water. The high vacuum and pressurization phases of the process typically achieve a 30-40 % volume reduction in the treated waste. The treated waste is then automatically or manually discharged into the handling system for feeding into the shredder.

**Installation**

See Section 11.3.1.7. MachinFabrik offers complete installation, commissioning and validation of their machines.

### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The MachinFabrik system requires an operator and is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

MachinFabrik has sterilizers in many states in India as well as Bangladesh and Mauritius.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

MachinFabrik equipment have programmable logic control-operated instrumentation for process control and user-friendly operator interfaces and SCADA systems. They offer optional materials handling, storage and transport equipment for hospitals, as well as equipment of central sterile supply departments.

### **Parameters for Specification**

Model based on the capacity, fuel specifications for the steam generator, electrical specifications, accessories and optional features.

### **Photographs**



L-R: Hazclave, Shred-O-Safe shredder

### **Vendor Information**

MachinFabrik has been involved in steam sterilization at least since the early 1990s and has expanded its products to include sterilizers for hospital instruments and pharmaceutical firms. The company has ISO:9001:2000 certification.

### **Contact Information**

MachinFabrik  
R/90, Rabale-MIDC,  
Thane Belapur Road,  
TTC Industrial Area,  
Navi Mumbai, India  
Tel-Fax : 91-22-67368200  
www.machinfabrik.com

## 12.1.8 MARK-COSTELLO

### **Type of Technology**

Gravity-displacement or vacuum autoclaves

### **Process Description**

Mark-Costello offers fully insulated horizontal autoclaves that can be gravity-displacement or vacuum, with a wedge-lock door ring, a ratchet handle for easy locking or unlocking of the door ring, a door with quadruple

safety features, and digital recorder and controller. Autoclaves can be built as carbon steel or stainless steel units. Many units have been in operation after 20 years.

### **Types of Waste Treated**

See Section 11.3.1.2. Mark-Costello autoclaves have been used for hospital waste, food waste at international airports, pharmaceutical waste, microbiological waste from laboratories, and healthcare waste at central treatment facilities.

### **Range of Capacities**

Model	Inner dimensions (diameter in feet x length in feet)	Number of Carts	Capacity (kg per cycle)
AS 23	2 x 3	Manual load	22
AS 36	3 x 6	Manual load	102
AS 47	4 x 7	3	204
AS 58	5 x 8	3	256
AS 510	5 x 10	4	340
AS 513	5 x 13	5	425
AS 515	5 x 15	6	510
AS 520 DD	5 x 20	4 (high volume)	680
AS 525 DD	5 x 25	5 (high volume)	850
AS 530 DD	5 x 30	6 (high volume)	1020
AS 620 DD	6 x 20	3 (extra high volume)	816
AS 634 DD	6 x 34	5 (extra high volume)	1361

DD = double doors

### **Pathogen Destruction**

See Section 11.3.1.4. The Mark-Costello autoclave has been shown to meet STAATT standards.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

See Section 11.3.1.6.

### **Installation**

See Section 11.3.1.7.

### **Maintenance**

See Section 11.3.1.8. The majority of maintenance is the replacement of the door gasket.

### **Job Potential**

The Mark-Costello system requires an operator and is highly automated. Some systems are totally automated. Job potential is low.

### **Locations where Technology is in Operation**

Mark-Costello autoclaves have been installed in many states of the US and Canada, as well as Australia, Brazil, Guam, India, Mexico, New Guinea, New Zealand, Peru, Romania, and the UK.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

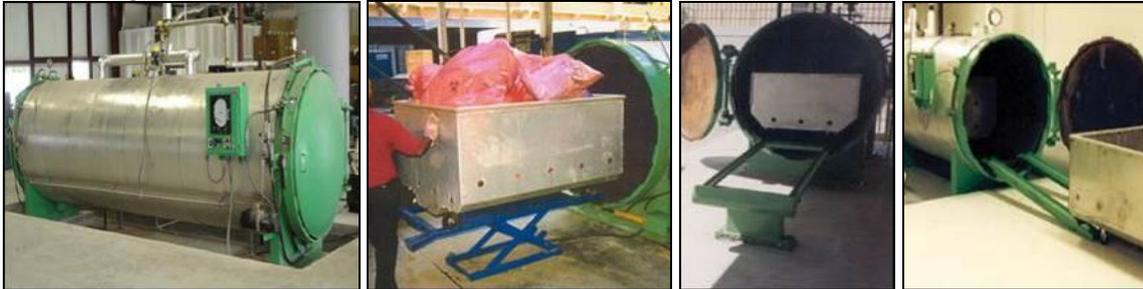
PLC control is an option. Accessories include pull-out drawers, cart ramps, or a hydraulic cart lifts to place carts into the autoclave; aluminum or stainless steel carts with steam-resistant casters; and all stainless steel units. The larger autoclaves can also be made with double doors, one at either end of the horizontal vessel. In addition, the

company offers a wide range of carts and other waste handling equipment, cart dumpers, shredders, grinders, heavy-duty granulators, compactors, balers, recycling equipment, and robotic systems for totally automated processing.

**Parameters for Specification**

Model based on the capacity, fuel specifications for the steam generator, electrical specifications, accessories and optional features.

**Photographs**



L-R: Mark-Costello autoclave (side view), waste cart being loaded in the AS58 autoclave via a hydraulic lift, AS 58 autoclave with a pull-out drawer for waste, autoclave with a cart ramp

**Vendor Information**

The Mark-Costello Co. was established in 1956 as a sales agency/distributor for lubrication systems. In 1971, the Waste Systems Division was formed to provide systems for handling solid and medical waste. The company has offices in California and Arizona in the United States and offices in Mexico.

**Contact Information**

The Mark-Costello Company  
 1145 East Dominguez Street  
 Carson, California 90746 USA  
 Tel: +1 (310) 637-1851  
 Fax: +1 (310) 762-2330  
<http://www.mark-costello.com>

12.1.9 MATACHANA / WEBECO

**Type of Technology**

Multiple vacuum autoclave

**Process Description**

Matachana autoclaves are made of stainless steel with a built-in steam generator, microcomputer control and touch screen, two standard programs and two test programs for healthcare waste, and a condensate treatment system and filter for air removal.

**Types of Waste Treated**

See Section 11.3.1.2. The steam sterilizers are designed to treat waste from hospitals, medical centers, laboratories, universities and research centers.

**Range of Capacities**

Model Series	Capacity
80 LR-1 RBE	7 to 15 kg/cycle
SC500 RBE	15 to 25 kg/hr
S1000 RBE	20 to 65 kg/hr
S2000 RBE	100 to 600 kg/hr

### **Pathogen Destruction**

See Section 11.3.1.4. The sterilizer achieves a Log<sub>10</sub> 6 reduction of bacillus spores.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

See 11.3.1.6. The sterilizer is automated. After the waste is loaded, several vacuum/steam injection cycles follow, then the chamber temperature is raised to 134°C for 20 minutes, followed by a final vacuum to remove steam.

### **Installation**

See Section 11.3.1.7.

### **Maintenance**

See Section 11.3.1.8.

### **Job Potential**

The Matachana sterilizer requires an operator and is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

Matachana technologies can be found in Spain, Germany, Argentina, Bolivia, Brazil, Chile, China and other Asian countries, Colombia, Czech Republic, Denmark, Ecuador, France, Mexico, Norway, Peru, Portugal, and Venezuela.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The autoclaves can also come with digital printers, recorders, waste containers, loading accessories, trolleys, specially designed internal racking for waste bags, post-treatment grinders and compactors with lifting and tilting mechanisms, weighing scales, and radioactivity detectors as optional features. The sterilizers can have single or double doors.

### **Parameters for Specification**

Model based on the capacity, electrical specifications, accessories and optional features.

### **Photographs**



L-R: Matachana autoclave series 80LR-1 RBE, SC500 RBE, S1000 RBE, and S2000 RBE

### **Vendor Information**

The Matachana Group has been involved in kitchen installations for hospitals and other industries since 1962. Matachana also provides sterilizers for hospitals, the pharmaceutical industry, laboratories, and research centers. The company is based in Spain with subsidiaries in France, Germany, Argentina and Malaysia, and distributors in more than 65 countries.

### **Contact Information**

Matachana

Almogávares, 174  
08018 Barcelona  
Spain  
Tel. 934 868 700  
Fax 933 098 692  
info@matachana.com  
http://www.matachana.com  
International: Tel. (+34) 933 008 504; Fax (+34) 934 854 354; int@matachana.com

#### 12.1.10 MEDCLEAN TECHNOLOGIES

##### **Type of Technology**

Autoclave

##### **Process Description**

The MedClean system is a digitally controlled autoclave that can be fully integrated with MedClean's proprietary light-weight and quiet aluminum-nickel alloy carts, a lifter/tipper system, and their proprietary low-speed high-torque shredders. The autoclave has a 15-inch touch screen and the control system is linked to a platform scale that measures the weight and number of carts being processed, and regulates autoclave temperature, pressure and cycle time. Total weight, process time and temperature, unique load identification number, time/date stamp, and operator identification are recorded.

##### **Types of Waste Treated**

See Section 11.3.1.2.

##### **Range of Capacities**

MedClean Series	Annual capacity* (lbs)
4300	600,000
4400	800,000
4500	1,000,000
5300	940,000
5400	1,250,000
5500	1,560,000

\*Capacity based on 12 hours operation, 6 days a week.

##### **Pathogen Destruction**

See Section 11.3.1.4.

##### **Emissions and By-Products**

See Section 11.3.1.5.

##### **Operation**

See Section 11.3.1.6.

##### **Installation**

See Section 11.3.1.7. MedClean offers installation, validation testing and training.

##### **Maintenance**

See Section 11.3.1.8. The technology requires electricity, water and steam. MedClean offers maintenance service including a quarterly preventive maintenance program.

##### **Job Potential**

The MedClean requires an operator with minimal training and is highly automated. Job potential is low.

##### **Locations where Technology is in Operation**

MedClean has focused primarily in the US and Canada markets.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The MedClean technology can be a fixed system, a mobile system or a system configured to fit in a standard-sized shipping container that can be placed at dock or grade level, with access to utilities via umbilical connections.

### **Parameters for Specification**

Quantity of healthcare waste to be treated, electrical specifications, desired configuration and accessories

### **Photographs**



L-R: Fixed MedClean system, proprietary cart, cart tipper

### **Vendor Information**

Founded in 1997, MedClean Technologies, Inc. (formerly Aduomed) provides systems for treatment of healthcare waste and destruction of confidential documents. The company offers a turnkey solution that integrates steam sterilization, shredding and disposal technologies in fixed, mobile or shipping container configurations.

### **Contact Information**

MedClean Technologies Corporate Headquarters  
3 Trowbridge Drive  
Bethel, Connecticut 06801 USA  
Tel: +1 (855) 438-6256  
jaccardi@GoMCLN.com  
<http://www.medcleantechnologies.com/>

## 12.1.11 ONSITE STERILIZATION/VARICLAVE

### **Type of Technology**

Multiple vacuum autoclave

### **Process Description**

OnSite Sterilization's VariClave is an integrated and automated stainless steel horizontal autoclave with a floating self-aligning door, internal water spray to cool the bin, and a full-color 17" touch panel display and controls using variable operating parameters that automatically adjusts according to the weight and characteristics of the load. The VariClave is used with a special bin and cart which separate for easy placement into the chamber. The system is capable of retaining records of process parameters, maintenance and training for seven years in a searchable database. The VariClave meets the ASME pressure vessel code.

### **Types of Waste Treated**

See Section 11.3.1.2. The technology is also used for treatment of waste from pandemics and quarantine waste, and the shredder can be used for destruction of confidential medical documents.

### Range of Capacities

The VariClave has a length of 4 m, width of 1.9 m and height of 2.4 m at the door, with a maximum capacity of 600 lbs (270 kg) per cycle.

### Pathogen Destruction

See Section 11.3.1.4. Validation tests of the VariClave show reductions of *Geobacillus stearothermophilus* spores greater than Log<sub>10</sub> 6.

### Emissions and By-Products

See Section 11.3.1.5.

### Operation

The operator can select one of a number of moist heat (steam) and dry heat sterilization programs depending on the type of waste and container. A typical steam cycle has three phases: the first phase involves a combination of gravity-displacement and multiple vacuum/steam injection cycles that can be repeated up to five times; a second phase involving maintaining exposure to steam at 121°C (250°F) for a residence time depending on weight and waste characteristics; and a third phase involving vacuum cycles and water sprays to cool and then remove moisture.

### Installation

See Section 11.3.1.7. In-service training and validation testing is provided.

### Maintenance

See Section 11.3.1.8.

### Job Potential

The OnSite system requires an operator with minimal training and is highly automated. Job potential is low.

### Locations where Technology is in Operation

OnSite Sterilization has installed technologies in the US.

### Cost Estimates

See Section 11.5.3.

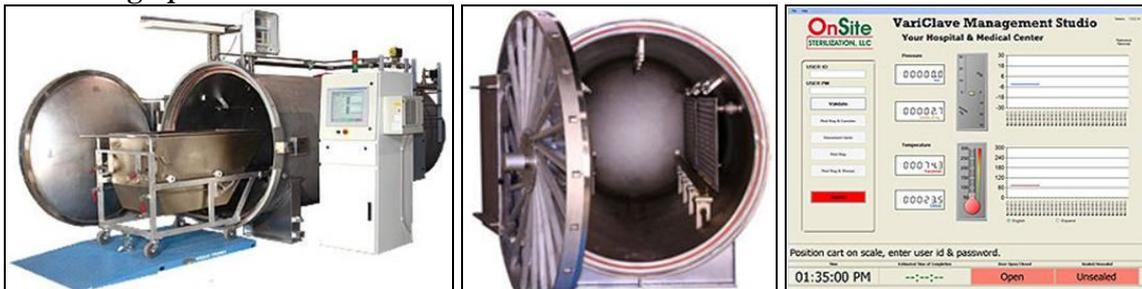
### Special Features

Other features include a bin lifter/tipper, rotary grinder (shredder), conveyor systems, an internal bin wash cycle, radiation monitoring, a special program to treat suction canisters, and automatic tracking of microbiological spore testing results.

### Parameters for Specification

Electrical specifications, desired system components and accessories

### Photographs



L-R: VariClave, view of inside the chamber, operator's screen

### Vendor Information

OnSite Sterilization began as a commercial treatment facility processing over 200 million pounds of healthcare waste in a 12 year period during which the company developed its steam sterilization and shredding system.

**Contact Information**

OnSite Sterilization, LLC.  
319 Commerce Court, Suite 103  
Pottstown, PA 19464-3478  
USA  
Tel.: +1 610-495-8214  
Fax: +1 610-495-8215  
Email: akoehler@askonsite.com  
www.askonsite.com

12.1.12 SAFEWASTE TECHNOLOGIES

**Type of Technology**

Autoclave

**Process Description**

Safewaste uses a horizontal gravity-displacement heavy-duty autoclave. It includes a boiler, weighing scale, controller, stainless steel basket and data logger to monitor the temperature in the waste. The system is simple and robust.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

The Safewaste autoclave processes 50 kg per hour.

**Pathogen Destruction**

See Section 11.3.1.4.

**Emissions and By-Products**

See Section 11.3.1.5.

**Operation**

Safewaste uses dual autoclaves for parallel operation and redundancy in the event one autoclave requires maintenance or repair. Waste is weighed, placed in fabric sacks and then in a steel basket. A data logger is placed inside the sack to monitor internal temperatures. The basket is manually loaded into the horizontal autoclave. The controller ensures that the waste is exposed to steam at a set temperature and pressure for a pre-determined time. Information in the data logger is downloaded and printed out as data tables and graphs for permanent documentation.

**Installation**

See Section 11.3.1.7.

**Maintenance**

See Section 11.3.1.8.

**Job Potential**

The Safewaste system requires two or more operators to load the waste in the basket and into the autoclave. Job potential is medium.

**Locations where Technology is in Operation**

Philippines

**Cost Estimates**

See Section 11.5.3.

**Special Features**

Installation and training are provided.

**Parameters for Specification**

Amount of waste generated, electrical specifications, desired accessories

**Photographs**



L-R: Waste in stainless steel wire basket; loading basket, starting the cycle

**Vendor Information**

Safewaste worked with an engineering firm that has been manufacturing autoclaves in the Philippines since 1964.

**Contact Information**

SafeWaste Inc.  
 3 Pallosapis St., Greenville  
 City of San Fernando, Pampanga 2000  
 Philippines  
 Tel.: +63 45 - 963 22 19  
 Fax: +63 45 - 963 22 19  
 safe\_waste@yahoo.com

12.1.13 SAN-I-PAK

**Type of Technology**

Vacuum autoclave

**Process Description**

The San-I-Pak system is a modular design with an automated loading feature for a touch-free operation. The vacuum autoclave has three positions: an upward tilt to maximize the capacity of the loading chamber, a horizontal position during sterilization, and a downward tilt to eject treated waste directly into a cart or a compactor with a 6:1 compaction ratio. The small systems use only two positions. The system can also have a separate section for placing regular domestic waste into the compactor. Since the design is modular and each autoclave in the series operates independently, the addition of chambers can meet any required processing capacity and having multiple chambers provides a built-in back-up. The equipment meets ASME and ANSI Z 245.1-1984 standards.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Range of capacities (lbs/hr)	Range of capacities (kg/hr)
-------	------------------------------	-----------------------------

2P-Series	25-87	11-39
3P Series	87-230	39-104
Source-Series	125-200	57-91
Mark-Series	106-400	48-180
Auto-Series	160-2240	73-1020
CAT-Series	1000+	454+

Because of the modular design and different chamber sizes, San-I-Pak systems can process from 11 kg to over 1000 kg per hour depending on the number of chambers installed. San-I-Pak compactors can process 1440 - 3000lbs per hour.

### **Pathogen Destruction**

See Section 11.3.1.4. Several tests, including tests by the US Environmental Protection Agency, of the San-I-Pak system have shown a Log10 6 or greater reduction in *Geobacillus stearothermophilus* spores.

### **Emissions and By-Products**

See Section 11.3.1.5.

### **Operation**

The basic operation entails placing the collection cart with the waste on the automatic cart dumper, using the controls to put the chamber in the load position (tilted up to maximize its capacity) and to load the waste, and placing the chamber in the sterilize position after the door is closed. The control system applies a high vacuum followed by steam injection and holds the temperature at a set time. After the sterilization cycle is finished, the steam is released and the door is opened. The operator pushes the “dump” button to tilt the chamber downward and eject the waste into a cart, a compactor, a roll-off container, an optional conveyor or shredder as desired.

### **Installation**

See Section 11.3.1.7. In-service training or week-long factory training is provided.

### **Maintenance**

See Section 11.3.1.8. The San-I-Pak system has a management system that anticipates the need for service, repairs and consumables. The system is remotely programmable and the telemetry allows technicians to diagnose and correct problems through a 24-hour request line. The company estimates an average of less than half a day per year of downtime per autoclave.

### **Job Potential**

The San-I-Pak system requires an operator and is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

San-I-Pak has more than 1,000 units operating worldwide including North America, South America, Central America, Europe, Middle East, New Zealand and Asia.

### **Cost Estimates**

See Section 11.5.3.

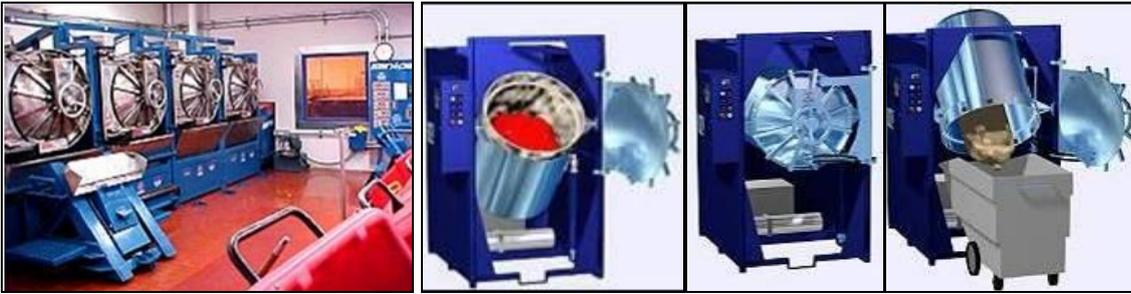
### **Special Features**

The San-I-Pak system has a telecommunications system for remote monitoring and diagnostics, a waste tracking system, an odor management system and strip printer for documentation. The San-I-Pak systems can also be designed for surge capacity in the event of a pandemic. The new Source-Series models use the collection cart itself as the treatment vessel and the AT-Series are three-position rotating sterilizers.

### **Parameters for Specification**

Capacity, number of chambers and chamber sizes desired, electrical specifications, additional components and accessories, such as compactors or conveyors, as needed

### **Photographs**



L-R: Example of the multi-chamber modular design; three positions: load, sterilize and dump

**Vendor Information**

San-I-Pak has been installing medical waste treatment autoclave since 1978 when it became the first non-incineration system approved for healthcare waste in New York and California. By 2000, the company had installed 600 units.

**Contact Information**

San-I-Pak  
 23535 South Bird Road  
 Tracy, CA 95304  
 USA  
 Tel.: +1 (209) 836-2310  
 Fax: +1 (209) 836-2336  
 Email: [info@sanipak.com](mailto:info@sanipak.com)  
<http://www.sanipak.com>

12.1.14 STERIDIUM

**Type of Technology**

Vacuum autoclave

**Process Description**

Steridium’s SD series of horizontal waste treatment autoclaves are fully jacketed and made of electro-polished stainless steel with vertical sliding doors that operate manually, electrically or pneumatically. A liquid ring vacuum pump or a water ejector system is used for vacuum cycles. The autoclave operates at 134 °C and the control and monitoring are done by a microprocessor system with a fluorescent display and a printer to document operating parameters. The autoclave can use available steam or can be provided with a stand-alone or built-in steam generator with an automatic blow-down system. The pressure vessels conform to the European pressure equipment directive (PED) 97/23/EC and are inspected by an internationally registered inspection authority (Lloyds Register) during production, testing and final certification.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Chamber Dimensions (in mm)	Internal Chamber (liters)
SD 500x750	500 diameter x 750 deep	150
SD 500x1000	500 diameter x 1000 deep	200
SD 460x760	460 diameter x 760 deep	160
SD 460x950	460 diameter x 950 deep	200
SD 460x1200	460 diameter x 1200 deep	250
SD 460x1450	460 diameter x 1450 deep	300
SD 660x915	660 wide x 660 high x 915 deep	400
SD 660x1250	660 wide x 660 high x 1250 deep	550
SD 660x1500	660 wide x 660 high x 1500 deep	650

SD 660x1850	660 wide x 660 high x 1850 deep	800
-------------	---------------------------------	-----

**Pathogen Destruction**

See Section 11.3.1.4.

**Emissions and By-Products**

See Section 11.3.1.5.

**Operation**

See Section 11.3.1.6.

**Installation**

See Section 11.3.1.7.

**Maintenance**

See Section 11.3.1.8.

**Job Potential**

The Steridium system requires an operator and is fully automated. Job potential is low.

**Locations where Technology is in Operation**

Steridium has installations in facilities ranging from teaching hospitals to remote small hospitals in both industrialized and developing countries.

**Cost Estimates**

See Section 11.5.3.

**Special Features**

Steridium autoclaves feature a reverse-flow system to ensure that even the drain lines are decontaminated. Steridium autoclaves incorporate an automatic blowdown feature into its steam generators to reduce the risk of pitting and stress corrosion cracking due to poor water quality in the steam. The chamber and doors are insulated with high density, CFC-free, mineral wool insulation.

**Parameters for Specification**

Chamber size, door configuration, type of vacuum system, steam generator if needed, electrical specifications, additional components and accessories, such as loading equipment

**Photographs**



L-R: Steridium SD series autoclave, Steridium display at the Hospimedica Exhibition in 2008

**Vendor Information**

Steridium has been making sterilizers for medical and laboratory applications since the 1980s. In addition to sterilizers for medical devices, they offer a line of large steam sterilizers for solid and liquid waste. A new manufacturing facility was opened in Brisbane, Australia in 2007.

**Contact Information**

Steridium

PO Box 5296  
 Q Super Centre  
 Queensland, 4218  
 Australia  
 Tel: +61 7 55 931 352  
 Fax: +61 7 55 931 876  
 Email: sales@steridium.com  
 www.steridium.com

12.1.15 TUTTNAUER

**Type of Technology**

Vacuum autoclave

**Process Description**

Tuttnauer's line of medical waste autoclaves uses a steam jacket, a water ring vacuum pump, and a hinged or automatic vertical sliding door. The evacuated air is decontaminated using a steam ejector or optional HEPA filter. The process is automated.

**Types of Waste Treated**

See Section 11.3.1.2.

**Range of Capacities**

Model	Chamber Dimensions (in cm)	Internal Chamber (liters)
Medium (diameter x length)		
5075HSG-BH	50 diameter x 75	160
Large (w x h x d)		
5596 –BH	508 x 508 x 970	250
55120 – BH	510 x 510 x 1210	310
6690 – BH	610 x 610 x 915	340
66120 – BH	610 x 610 x 1215	450
6990 – BH	610 x 910 x 920	510
6671130 - BH	660 x 710 x 1295	610
69120 – BH	610 x 910 x 1215	680
69150 – BH	610 x 910 x 1515	840
69180 – BH	610 x 910 x 1815	1010
T-MAX 15	660 x 1220 x 1620	1300
Bulk (w x h x d)		
364853	92 x 122 x 136	1500
364860	92 x 122 x 151	1700
364872	92 x 122 x 182	2000
3648144	92 x 122 x 363	4000

**Pathogen Destruction**

See Section 11.3.1.4. Tuttnauer autoclaves can achieve a 6 Log<sub>10</sub> reduction of biological indicators.

**Emissions and By-Products**

See Section 11.3.1.5.

**Operation**

Tuttnauer autoclaves have manual or automatic loading systems. Waste can be placed in a specialized loading cart with barriers around each shelf and a drain for any leaks in the bottom shelf. The system can be controlled using a control panel with continuous display of operating parameters and the ability to customize processing cycles. A more advanced touch-screen control system is also available. Tuttnauer provides four standard pre-

programmed processing cycles: two solid waste, a liquid waste, and a solid-liquid waste programs. The treated waste can be shredded and compacted for disposal at a landfill.

#### **Installation**

See Section 11.3.1.7. Tuttnauer can provide planning, design and installation services.

#### **Maintenance**

See Section 11.3.1.8. Tuttnauer provides a list of daily, weekly, monthly, quarterly, semi-annual and annual preventive maintenance instructions.

#### **Job Potential**

The Tuttnauer system requires an operator and is fully automated. Job potential is low.

#### **Locations where Technology is in Operation**

Tuttnauer autoclaves for hospital, laboratory or waste applications have been installed in many countries including Bulgaria, China, Colombia, Cyprus, Germany, Greece, Hungary, India, Kenya, Netherlands, Panama, Poland, Russia, Singapore, Slovakia, Turkey, United States, and Vietnam.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

Tuttnauer autoclaves have built-in cooling coils to speed up cooling and a flexible temperature probe for monitoring liquid sterilization. Customers can choose between a standard or touch-screen control system with both mechanical and digital monitoring of parameters. The autoclave can have single or double doors. In addition to the four pre-programmed cycles, additional programs are also available. The autoclaves have multiple safety features. Steam can be provided by an optional generator or using existing building steam. The pressure vessel is warranted against material or workmanship failure for 15 years.

#### **Parameters for Specification**

Chamber volume, door configuration, control system, type of vacuum system, steam generator if needed, electrical specifications, additional components and accessories, such as loading carts

#### **Photographs**



L-R: Medium-size, large-size, and bulk autoclave series

#### **Vendor Information**

Tuttnauer has been providing sterilization and infection control products to hospitals, clinics, research institutions and laboratories for over 80 years.

#### **Contact Information**

Tuttnauer Co. Ltd., Har Tuv Industrial Zone, B P.O. Box 170, Beit Shemesh, 99000, Israel  
E-mail: [info@tuttnauer-hq.com](mailto:info@tuttnauer-hq.com)

Tuttnauer Europe b.v.  
Paardeweide 36, 4824 EH,

P.O.B. 7191, 4800 GD Breda  
The Netherlands  
Tel: +31 (0) 765 423 510  
Fax: +31 (0) 765 423 540  
E-mail: info@tuttnauer.nl  
www.tuttnauer.com

Tuttnauer USA Co.  
25 Power Drive,  
Hauppauge, NY 11788  
Tel: +800 624 5836, +631 737 4850  
Fax: +631 737 0720  
E-mail: info@tuttnauer.com  
www.tuttnauerUSA.com

## 12.2 HYBRID AUTOCLAVE SYSTEMS

### 12.2.1 CELITRON

#### **Type of Technology**

Hybrid autoclave system

#### **Process Description**

The Celitron Integrated Sterilizer & Shredder (ISS) system does both shredding and steam sterilization in one vessel. The vessel has a motor-driven shaft with shredding blades that rotate at 300 to 1100 rpm in two directions and can reduce the waste volume by 80%. The unit is compact and can fit in a 3 x 4 meter room. The system comes with a steam generator, treatment for the feed water, and a draining system. The vessel has internal sprinklers for cleaning.

#### **Types of Waste Treated**

See Section 11.3.2.2. The shredder can handle sharps, dialyzers, syringes, papers, cloth, plastic and glass.

#### **Range of Capacities**

The ISS can handle about 48 kg per hour.

#### **Pathogen Destruction**

See Section 11.3.2.4.

#### **Emissions and By-Products**

See Section 11.3.2.5.

#### **Operation**

The entire process is automated, including the opening and closing of the door. The vessel tilts upward for waste loading then turns and rotates automatically. The total cycle time including sequences of shredding and sterilization can be as fast as 25 minutes. During sterilization, the liquid components of the waste in the vessel are vaporized, re-condensed and drained to a municipal sewer. The resulting waste is dehydrated.

#### **Installation**

Installation is simple and takes about a day. The main installation requirements are water, electricity, and drain.

#### **Maintenance**

See Section 11.3.2.8.

#### **Job Potential**

The ISS system is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

Celitron is based in Hungary and has contacts in Australia, Germany, Mexico, Netherlands and Switzerland for services in those regions.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Celitron evaluates training needs and provides training for personnel at different levels.

### **Parameters for Specification**

Steam pressure if available, electrical specifications

### **Photographs**



L-R: ISS unit in the tilted and vertical positions; close-up of the shredder blades

### **Vendor Information**

Celitron Medical Technologies manufactures medical waste sterilization & management systems as well as infection control equipment for hospitals and dental clinics. They also offer control systems and bench-top, medium and large steam sterilizers for other applications.

### **Contact Information**

Celitron Medical Technologies Kft.  
Avar Utca 5, 2600 Vác  
Hungary  
Tel.: (36) 27512267  
Fax: (36) 27512268  
Email: [info@celitron.com](mailto:info@celitron.com)  
[www.celitron.com](http://www.celitron.com)

## 12.2.2 ECODAS

### **Type of Technology**

Hybrid autoclave system

### **Process Description**

The Ecodas system is a vertical cylindrical jacketed steam sterilizer combined with an internal shredder. Waste is loaded at the top. When the top lid is closed, a paddle pushes the waste into a double-shaft heavy-duty shredder causing waste pieces to fall into a lower chamber. The inside of the whole vessel is heated to 138 °C and a pressure of 3.8 bars. After exposure for about 10 minutes, cooling water is sprayed along the outside walls of the inner chamber to cool the waste to 80 °C. A vacuum cycle is used to condense steam from the waste after which the bottom lid is opened to unload the treated waste onto a bin. A programmable logic controller controls the process. The Ecodas meets ASME, European Directive and other norms.

### **Types of Waste Treated**

See Section 11.3.2.2. The Ecodas could also treat pathological waste.

### Range of Capacities

Model	Capacity (kg/cycle)	Cycle time (min)
T150	15 - 25	30
T300	30 - 45	30
T1000	100 - 150	40
T2000	200 - 300	60

### Pathogen Destruction

See Section 11.3.2.4. Tests have shown a 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### Emissions and By-Products

See Section 11.3.2.5.

### Operation

The main operational steps are: loading, shredding, heating, sterilization, cooling, draining, vacuuming, and unloading. The operator loads the waste at the top by a manual or automatic operation.

### Installation

The main installation requirements are water, electricity, steam supply, compressed air, drain and air vent. The machine can be installed at floor level with a stair case leading to the top of the vessel. Another configuration is to have the upper part of the vessel above the loading dock level or at a higher floor, with the bottom of the vessel at ground level or lower floor. Ecodas can provide a turn-key installation.

### Maintenance

See Section 11.3.2.8.

### Job Potential

The Ecodas system requires an operator and is fully automated. Job potential is low.

### Locations where Technology is in Operation

Ecodas systems have been installed in 50 countries including Albania, Algeria, Argentina, Azerbaijan, Bosnia, Brazil, China, Cyprus, Ecuador, Egypt, French Guiana, French Polynesia, Guadalupe, Honduras, India, Iraq, Iran, Jamaica, Jordan, Kosovo, Latvia, Lebanon, Libya, Mexico, Morocco, New Caledonia, Nigeria, Panama, Reunion Island, St. Lucia, Syria, Turkmenistan, UAE, and Venezuela.

### Cost Estimates

See Section 11.5.3.

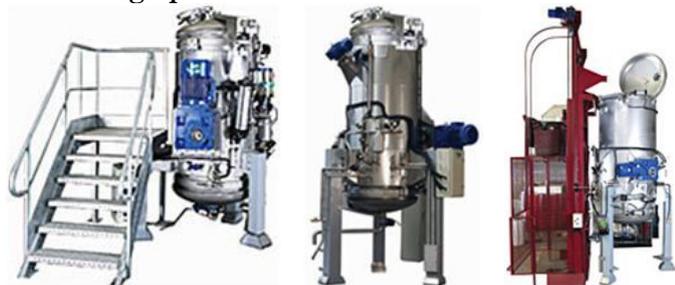
### Special Features

The Ecodas system automatically keeps records. The larger system can be used with an automated waste bin tipper.

### Parameters for Specification

Model, installation configuration, available steam pressure, electrical specifications

### Photographs



L-R: Models T150 or T300, T1000,

### **Vendor Information**

Ecodas developed its specialty in the manufacturing of pressurized vessels with applications in the textile, food-processing and medical waste industries for over 20 years.

### **Contact Information**

Ecodas  
28, rue Sébastopol  
59100 Roubaix  
France  
Tel: (33) 03 20 70 9865  
Fax: (33) 03 20 24 2381  
Email: [contact@ecodas.com](mailto:contact@ecodas.com)  
[www.ecodas.com](http://www.ecodas.com)

### 12.2.3 ECOLOTEC

#### **Type of Technology**

Hybrid autoclave system

#### **Process Description**

The Ecolotec system is a compact, computer-controlled unit that combines a pressure vessel with internal shredding. The sterilizing bowl, which tilts to facilitate loading and unloading, is a jacketing pressure vessel with a vacuum system along with internal rotating knife hammers that simultaneously sterilizes and shreds the waste. The knife hammer blades rotate at 1500 to 1750 rpm. Evacuated air is passed through HEPA and activated carbon filters. The touch-screen computer controls have a digital readout and memory card. The system achieves up to 80% volume reduction.

#### **Types of Waste Treated**

See Section 11.3.2.2. In addition to most types of healthcare waste, the Ecolotec can also handle pathological waste.

#### **Range of Capacities**

Since the Ecolotec can decontaminate the waste in about 10 minutes, the 221 liter capacity bowl can process about 160 kg per hour with four processing cycles per hour.

#### **Pathogen Destruction**

See Section 11.3.2.4. The Ecolotec can achieve 6 Log<sub>10</sub> reduction of biological indicators.

#### **Emissions and By-Products**

See Section 11.3.2.5.

#### **Operation**

The Ecolotec bowl tilts for loading of the waste. The system operation involves a pre-vacuum phase, injection of superheated steam, and internal rotation of the blades. After the sterilization parameters are met, a post-vacuum system eliminates any residual moisture and air is added to equalize pressure and cool the treated waste, which is then removed and disposed as regular waste.

#### **Installation**

The installation requires three-phase power, existing steam, cold water, drain, compressed air, and ventilation.

#### **Maintenance**

See Section 11.3.2.8.

#### **Job Potential**

The Ecolotec system requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

United States

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Ecolotec is designed to fit in a normal office-size space. One of its safety features is a safety program which will automatically lengthen the sterilization time in the event of a rotary tool failure. Hard copies of the operating data can be printed out as documentation.

### **Parameters for Specification**

Required capacity, available steam pressure, electrical specifications

### **Photographs**



L-R: Ecolotec unit, close-up of sterilizing bowl tilted during loading

### **Vendor Information**

The device was developed by Wolf A. von Lersner, then director of engineering of a major food processing company, in collaboration with Stephan Machinery GmbH in Hameln, Germany. The equipment was patented in 1993. Ecolotec, LLC, of which Wolf von Lersner is a founder, has purchased patent rights and exclusive marketing rights for the technology. Distributors are located in North America, Middle East, Caribbean, and Norway (for Europe, Russia and Africa).

### **Contact Information**

Ecolotec, LLC  
196 Highlands  
Union Grove, AL 35175  
USA  
Tel: 1-256-270-4335  
Fax: 1-256-837-4091  
Email: [dallen32843@gmail.com](mailto:dallen32843@gmail.com)  
[www.ecolotec.com](http://www.ecolotec.com)

## 12.2.4 HYDROCLAVE

### **Type of Technology**

Hybrid autoclave system

### **Process Description**

The Hydroclave combines a pressure vessel with internal rotating arms to dehydrate and fragment the waste. The pressure vessel has an outer steel jacket into which steam is introduced. As the mixing arms rotate, they break open bags and containers and cause them to tumble against the hot surfaces. Heat from the jacket is absorbed by the fragmented waste to form steam inside the vessel. If there is not enough moisture in the waste, the Hydroclave automatically injects steam into the pressure vessel.

### Types of Waste Treated

See Section 11.3.2.2. In addition to most types of healthcare waste, the Hydroclave can also handle pathological waste.

### Range of Capacities

Hydroclave models can process from 275 kg to over 18 tonnes per day.

Model	Maximum capacity (kg/hr)
H-07	34
H-15	70
H-25	116
H-40	178
H-65	347
H-100	463
H-150	714
H-200	857
H-250	1023

### Pathogen Destruction

See Section 11.3.2.4. The Hydroclave can achieve a 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### Emissions and By-Products

See Section 11.3.2.5.

### Operation

The typical operation is as follows. Waste is dropped into one or more loading doors and the door(s) are closed. The controllers start the heating and fragmentation process, during which steam is added to the outside jacket and the fragmenting arms begin to rotate. The pressure is adjusted and the waste is exposed to moist heat for a pre-determined period. After decontamination, the vessel is then de-pressurized while maintaining heat to dry the waste. Finally, steam to the jacket is shut off, the unloading door is opened, and the mixing arms reverse rotation to act as an unloading mechanism.

### Installation

The installation requires an electrical supply, water supply, steam supply, and sanitary sewer discharge.

### Maintenance

See Section 11.3.2.8.

### Job Potential

The Hydroclave system requires an operator and is automated. Job potential is low.

### Locations where Technology is in Operation

The technology has been installed worldwide including Albania, Argentina, Canada, China, Egypt, Greece, Guyana, India, Iran, Lebanon, Mexico, New Caledonia, Niger, Philippines, Romania, Russia, Sri Lanka, South Africa, Turkey, United Kingdom, and United States.

### Cost Estimates

See Section 11.5.3. System costs do not include installation, commissioning, training, shipping and local fees such as approvals or tariffs.

### Special Features

The Hydroclave self-unloads and could be combined with a conveyor system to an optional shredder and/or compactor. The recorder puts out a printout for documentation. The steam condensate used for the outer jacket is recycled to conserve water. The small models include a built-in boiler. Training includes maintenance, troubleshooting and minor fixes. Data from the equipment can use an optional

### Parameters for Specification

Required capacity, available steam pressure, electrical specifications

### **Photographs**



L-R: Models H-07, H-100, H-250

### **Vendor Information**

The company started in 1994 with the development of a prototype sterilizer that was tested by the University of Ottawa and submitted to the Canadian Government for review. It has since expanded worldwide and maintains a 24-hour hotline.

### **Contact Information**

Hydroclave Systems Corp.  
672 Norris Court  
Kingston, Ontario  
Canada K7P 2R9  
Tel: 1 (613) 389-8373  
Fax: (613) 389-8554  
Email: [hydrosys@istar.ca](mailto:hydrosys@istar.ca)  
[www.hydroclave.com](http://www.hydroclave.com)

## 12.2.5 MEDFRESHE/NARULA GROUP

### **Type of Technology**

Hybrid autoclave system

### **Process Description**

The Unison Narula Group (Narula Exports) has an integrated sterilizer and internal shredder (ISS) with a built-in steam generator for infectious waste. The sterilizer operates up to 138°C and 2.4 bars. The vessel has a motor-driven shaft with shredding/crushing blades rotating in two directions inside the vessel resulting in up to 80% volume reduction. In addition, the vessel is supported by two arms which allow the vessel to rotate to three positions for loading, treatment and unloading. Internal sprinklers automatically clean the vessel and a reverse-osmosis system provides water to the steam generator. A microprocessor controls the system and operating status is shown in a digital touch screen display. Operating parameters are printed for documentation. The system is equipped with an energy-saving mode, alarms, and remote diagnostics. The ISS complies with various EN and ISO standards.

### **Types of Waste Treated**

See Section 11.3.2.2. The shredder rotates from 300 to 1400 RPMs depending on operations to shred paper, cloth, plastic and glass.

### **Range of Capacities**

The chamber size is 150 liters. The cycles are specified by the user but the general program involves a 5 minute sterilization/shredding cycle followed by a fast exhaust and 5 minute drying cycle.

### **Pathogen Destruction**

See Section 11.3.2.4.

### **Emissions and By-Products**

See Section 11.3.2.5.

### **Operation**

The basic operation is comprised of loading, treatment, waste unloading and disposal. The vessel rotates into three different positions for loading, treatment and unloading.

### **Installation**

The main installation requirements are electricity, optional inlet steam, water, compressed air for controls, drain and ventilation.

### **Maintenance**

See Section 11.3.2.8.

### **Job Potential**

The ISS is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

The ISS is found in India and exported to other countries especially in SAARC, ASEAN, European, African and Gulf countries.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Narula Group provides a basic layout of a waste treatment plant designed around an ISS. The company also exports other hospital products such as instrument sterilization autoclaves and waste bins.

### **Parameters for Specification**

Required capacity, electrical specifications

### **Photographs**



L-R: ISS unit, ISS unit during loading, waste after treatment and shredding

### **Vendor Information**

The company began in 1953 as a supplier of medical supplies. It is now a manufacturer and exporter of medical equipment and products to the global market with a presence in 49 countries. Narula Exports is a government recognized export house.

### **Contact Information**

MedFreshe/Narula Exports  
Marketing Office, Narula's Tower-II  
2 & 3, Central Market, Punjabi Bagh (West)  
New Delhi – 110026  
India  
Tel: +91-11-4545 999, -2522 4102, -2522 3873

Fax: +91-11-2322 8702

Email: [hrn@narulaexports.com](mailto:hrn@narulaexports.com), [medfreshe@narulaexports.com](mailto:medfreshe@narulaexports.com)

[www.narulaexports.com](http://www.narulaexports.com)

#### 12.2.6 MEDIVAC METAMIZER

##### **Type of Technology**

Hybrid autoclave system

##### **Process Description**

MediVac's MetaMizer 240 SS system combines autoclave sterilization and internal shredding. It uses an on-board boiler, a weighing scale, waste bins with RFID (radio-frequency identification device) which are scanned, and an automatic waste bin dumping system. The system is fully automated and uses a touch-screen programmable logic controller. Data is recorded in an SD card and can be remotely accessible.

##### **Types of Waste Treated**

See Section 11.3.2.2. The MetaMizer could potentially treat pathological waste.

##### **Range of Capacities**

The MetaMizer can treat about 240 liters every 15 minutes or about 200 kg per hour.

##### **Pathogen Destruction**

See Section 11.3.2.4. The system can achieve a 6 Log<sub>10</sub> reduction of biological indicators.

##### **Emissions and By-Products**

See Section 11.3.2.5.

##### **Operation**

The waste bin is weighed, scanned and emptied automatically through a hopper into the inner chamber. The waste is circulated around the vessel and through the shredder multiple times. After the sterilization time is completed, the sterilized waste, which is reduced by about 90% in volume, is purged into a 240-liter bin inside the machine. The waste is then removed for disposal in a landfill.

##### **Installation**

The main installation requirements are electricity, water and a sewer drain.

##### **Maintenance**

MediVac has a 6-month service check and an annual maintenance schedule.

##### **Job Potential**

The MetaMizer system requires an operator and is fully automated. Job potential is low.

##### **Locations where Technology is in Operation**

The MetaMizer is found in Australia, Japan and Russia.

##### **Cost Estimates**

See Section 11.5.3. Equipment leases are available in Australia.

##### **Special Features**

Single or multiple units can be monitored by Internet or phone line. Staff training only takes one to two hours with 7 hours of hands-on guidance. No specialize staff is required.

##### **Parameters for Specification**

Required capacity, electrical specifications

**Photographs**



MetaMizer 240 SS

**Vendor Information**

The company has been in business for 14 years and has won some quality and environmental awards. It has distributors in Cyprus, India, Greece, Japan, and Russia.

**Contact Information**

MediVac Technology  
 Unit 8 / Lot 1B Kleins Road, Northmead NSW 2152 Australia  
 P O Box 656 Baulkham Hills NSW 1755  
 Australia  
 Tel.: + 61 2 9630 0633 | +61 2 9922 3640  
 Fax: +61 2 9630 0533  
 Email: info@medivac.com.au  
 www.medivac.com.au

12.2.7 METAN

**Type of Technology**

Hybrid autoclave system

**Process Description**

Metan Green Health & Environmental Services provides three basic types of Akar autoclave and hybrid autoclave systems. One is a standard vacuum autoclave with a post-treatment shredder. Another is an L-shaped design that incorporates vertical loading followed by shredding and then treatment in a horizontal autoclave. The shredder is a cassette design which allows the user to easily remove it for maintenance. The third type is a completely vertical system with vertical loading, shredding and then treatment in a vertical autoclave. The vertical autoclave has an internal mixer to agitate the waste. Akan autoclaves range in sizes up to 5 meters diameter and 45 meters long for diverse applications.

**Types of Waste Treated**

See Section 11.3.2.2.

**Range of Capacities**

Model	Capacity (kg/hr)
Post-shredding autoclave 500	500
Post-shredding autoclave 1000	1000
Pre-shredding L250	250
Pre-shredding L500	500
Pre-shredding V	250

**Pathogen Destruction**

See Section 11.3.2.4.

**Emissions and By-Products**

See Section 11.3.2.5.

### **Operation**

All the technologies are fully automated. The post-shredding autoclaves have a ramp for loading carts into single- or double-door vacuum autoclaves operating at 140-155°C and 4-6 bars, the carts are brought to a separate vertical shredder with an automatic lift and a 2000 liter shredder hopper. Shredded waste can be discharged directly into an open truck container. The pre-shred L type system has an automatic lift and container feeding using automated hydraulic discharging doors. The internal two-shaft shredder is vertical with a waste mixing and discharging auger, and is connected to a horizontal autoclave, hence the L-shape. The vacuum autoclave operates at 135-140°C and 4-5 bars. The pre-shredding V is similar to the L type except that the system is completely vertical and uses mixing wings to mix and discharge the waste. The vertical autoclave can discharge directly into a truck. Units come with touch screen colored displays in Turkish or English and PLC controls with Internet connection.

### **Installation**

The main installation requirements are electricity, water, drain and ventilation. There has to be sufficient vertical space for the L and V shape units.

### **Maintenance**

See Section 11.3.2.8.

### **Job Potential**

The units are fully automated. Job potential is low.

### **Locations where Technology is in Operation**

The Metan systems are found in various cities in Turkey.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Metan can provide different types and sizes of containers. The company also provides transport and logistics of medical waste, planning and project management, architectural planning for plant construction, and assistance in recycling of sterilized medical waste.

### **Parameters for Specification**

Required capacity, electrical specifications, space

### **Photographs**



L-R: Pre-shredding L type, Pre-shredding V type, cassette-type shredder

### **Vendor Information**

Metan Co. Ltd has been working in the medical waste field since 1998 as both a consulting company and technology provider. Its founder, Dr. Cemal Kaldirimci, developed the integrated autoclave and shredding systems. They have also been distributors of various European and American medical waste treatment technologies. Metan had previously partnered with Optima Engineering to form OptiMet. Metan works with Akar Machinery Industry Trade Co., Ltd. which has been manufacturing autoclaves since 1990.

### Contact Information

Metan Green Health & Environmental Services  
Metan Uluslararası Ticaret ve Danışmanlık LTD Şti.  
Mustafa Kemal Mahallesi Barış Sitesi 2089. Sokak No:6  
06800 / Çankaya / Ankara  
Turkey  
Tel: +90 (312) 285 70 65  
Fax: +90 (312) 285 95 30  
E-Mail: info@metan.com.tr  
http://metan.com.tr/

### 12.2.8 REDBAG SOLUTIONS

#### Type of Technology

Hybrid steam treatment system

#### Process Description

Redbag Solutions offers the SSM-150 technology which combines simultaneous exposure of waste to steam at 133°C/water and a cutting system. A filter-separator unit removes waste from the treated waste residue. The compact SSM is intended for on-site use and reduces waste volume up to 90%.

#### Types of Waste Treated

See Section 11.3.2.2. The SSM can also be used to destroy confidential papers.

#### Range of Capacities

The SSM can treat about 70 kg per hour.

#### Pathogen Destruction

See Section 11.3.2.4. Various microbial inactivation tests were conducted to show the effectiveness of the SSM against *Geobacillus stearothermophilus* and other microorganism.

#### Emissions and By-Products

See Section 11.3.2.5.

#### Operation

Waste bags are loaded through a 24-inch diameter hatch. After the hatch is closed, the treatment tank is pressurized with steam. A macerator pump then grinds and circulates the waste under pressure and steam. The waste is then cooled with fresh water and sent to the filter separator which separates the liquid and solid residue. The liquid goes down the drain into the sanitary sewer while the solid residues are collected in a container for disposal. The computer prints a form that verifies the process. The operator opens the hatch to add waste, empties the filter separator, and pushes the Start button for the next cycle.

#### Installation

The equipment requires electricity, hot water, cold water, sanitary drain, vent, steam supply, compressed air, and phone line.

#### Maintenance

See Section 11.3.2.8.

#### Job Potential

The SSM system requires an operator and is fully automated. Job potential is low.

#### Locations where Technology is in Operation

The SSM is installed in the United States.

### **Cost Estimates**

See Section 11.5.3. Equipment leases are available in the United States.

### **Special Features**

Redbag Solutions provides a turnkey process and Web-based monitoring.

### **Parameters for Specification**

Required capacity, electrical specifications

### **Photographs**



L-R: SSM technology, before and after photos of waste

### **Vendor Information**

The device, originally referred to as the steam sterilization macerator, was developed by a dentist in the early 1990s. It is now sold by Red Bag Solutions.

### **Contact Information**

Red Bag Solutions  
3431 Benson Avenue, Suite 100  
Baltimore, MD 21227  
USA  
Tel.: 1-443-524-4245, 1 877-973-3224  
Fax: 443-524-4250  
Email: [info@redbag.com](mailto:info@redbag.com)  
[www.redbag.com](http://www.redbag.com)

## 12.2.9 SAZGAR

### **Type of Technology**

Hybrid autoclave system

### **Process Description**

Sazgar has a specially designed sterilizer with an internal shredder for hospital and pharmaceutical waste applications. It has an internal working temperature of about 135°C and internal working pressure of 2.2 bars. The chamber is made of 316L stainless steel and the steam jacket and structure are of 304 stainless steel. The shredder is comprised of two banks of blades rotating in opposite direction with automatic reversal to prevent jamming and clogging. A volume reduction of about 80% and mass reduction of 30% can be achieved. The system uses a water seal ring pump for the vacuum cycle, a microbiological filter for air, PLC-based controls, and a touch screen LCD display for monitoring. The system can be installed with an electrical steam boiler or connected to an existing central steam plant. The treatment cycle is 45 minutes.

### **Types of Waste Treated**

See Section 11.3.2.2.

### **Range of Capacities**

The Sazgar AWS series include the internal shredder and have the following capacities:

Model	Capacity (kg/hr)	Capacity (liters/cycle)
AWS-500	76	500
AWS-1000	100-150	1000
AWS-2000	200-300	2000

Sazgar also makes sterilizers without an internal shredder; the AWOS-500 and AWOS-1000 have the same capacities as their hybrid counterparts. Sazgar makes a smaller sterilizer without an internal shredder, AWOS-300, which can treat 300 liters per cycle.

**Pathogen Destruction**

See Section 11.3.2.4. The system has a device for placing microbiological indicators in the chamber.

**Emissions and By-Products**

See Section 11.3.2.5.

**Operation**

The infectious waste is fed using an automatic elevating trolley into the shredder. Shredding begins after the top door is closed. The sterilization cycle includes an automatic three-pulse pre-vacuum cycle, steam exposure at 138°C for 10 minutes, separation of the solid and liquid waste, a post- vacuum cycle, and a cooling cycle to reduce the waste temperature after which the unloading door is opened. Sterile liquid waste is discharged into the septic system.

**Installation**

The main installation requirements are electricity, inlet steam (if an electric steam generator is not included), water, and compressed air for controls.

**Maintenance**

See Section 11.3.2.8.

**Job Potential**

The Sazgar technology is fully automated. Job potential is low.

**Locations where Technology is in Operation**

The Sazgar technology has been used in several national industrial autoclave projects. They provide technologies and services to Iran and the Middle East region.

**Cost Estimates**

See Section 11.5.3.

**Special Features**

Sazgar also makes sterilizers without internal shredders for infectious waste. They offer trolleys for collection and handling of the waste.

**Parameters for Specification**

Required capacity, electrical specifications

**Photographs**



AWS sterilizer with shredder, AWS shredder blades, AWOS-500 sterilizer without shredder

### **Vendor Information**

Sazgar was founded in 1992 in Iran and has been manufacturing CE-marked autoclaves and infectious waste sterilizers for hospital, clinical, pharmaceutical and laboratory applications.

### **Contact Information**

Sazgar  
No. 457, Gharehtapeh Station  
Shahriar Road, Shahriar  
Tehran, Iran  
P.O. Box 33515-198, Tehran  
Iran  
Tel./Fax: +98 262 3290130-9  
Email: info@sazgarmed.com  
www.sazgarmed.com

## 12.2.10 T.E.M. STERIFLASH AND STERI2FLASH

### **Type of Technology**

Hybrid steam treatment system

### **Process Description**

The Steriflash combines internal shredding and steam sterilization. It consists of a hopper where a bactericide is injected, a mechanical arm on the transparent lid to push the waste into the shredder, a dual-shaft shredder, and a treatment tank with a press to separate solids and liquids. Control is automated by a programmable controller that stores up to two weeks of data. A temperature of 135°C at 2.3 bar pressure for 20 minutes is achieved. Minute-by-minute data is printed out in a ticket tape along with a certificate of completion at the end of the disinfection cycle. The Steriflash has an internal cleaning cycle which takes place every 20 cycles. The equipment is intended for a small hospital or departments of a large hospital.

### **Types of Waste Treated**

See Section 11.3.2.2.

### **Range of Capacities**

The Steriflash processes 80 liters of waste in 40 minutes, with about 3 minutes of manual operation for shredding. The Steri2flash processes 200 liters of waste.

### **Pathogen Destruction**

See Section 11.3.2.4.

### **Emissions and By-Products**

See Section 11.3.2.5.

### **Operation**

A bactericide is first injected into the hopper and the waste is loaded in. The transparent lid is closed over the hopper and the waste is shredded while the operator uses the mechanical arm to push the waste into the shredder; this takes about 5 minutes. The shredded waste falls into the treatment tank and is then decontaminated with steam for a set period. The waste is then pressed, liquids are released down the drain, and the solids are discharged. Bactericide is sprayed in the hopper area in preparation for a new cycle.

### **Installation**

The equipment requires electricity, water, and drainage.

### **Maintenance**

See Section 11.3.2.8. Parts that wear out are accessible for maintenance. Daily and weekly maintenance take about 10 minutes.

### **Job Potential**

The Steriflash requires an operator and is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

Distributors for the Steriflash are found in Algeria, Czech Republic, France, Germany, Greece, India Iran, Iraq, Japan, Jordan, Kuwait, Lebanon, Libya, Malaysia, Morocco, Panama, Poland, Romania, Russia, Saudi Arabia, Spain, St. Bart, Syria, Tunisia, Ukraine, United Arab Emirates, United Kingdom, Uruguay, and Venezuela.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Steriflash has several safety features including filtering of any gaseous emissions and safety relay switches. Options include the capability of remote monitoring and diagnostics via modem and Internet, weighing the waste at the output, remote control, and a wide selection of paint colors.

### **Parameters for Specification**

Required capacity, electrical specifications

### **Photographs**



L-R: Steriflash showing the mechanical arm, controls, and bactericide spray gun; photos of waste before and after processing

### **Vendor Information**

T.E.M. was founded in 2002 and designs and manufactures medical waste shredders and processing equipment.

### **Contact Information**

T.E.M (Technologies Environnement et Médical) Steriflash

Ste T.E.M - Hôtel d'entreprise

ZI la pradelle voie la pradelle

31190 Auterive

France

Tel:(+33)5-34-28-02-34

Fax:(+33)5-34-28-02-37

email: [info@steriflash.fr](mailto:info@steriflash.fr); [info@tem-lab.com](mailto:info@tem-lab.com)

[www.steriflash.fr/gb/general-gb.htm](http://www.steriflash.fr/gb/general-gb.htm); [www.tem-lab.com](http://www.tem-lab.com)

## 12.2.11 TEMPICO ROTOCLOAVE

### **Type of Technology**

Hybrid autoclave system

### **Process Description**

The Rotoclave is a pressure vessel with a rotating internal drum fitted with an angular helix. The combined effects of the steam and the forces due to rotation, as containers are pushed against the helix of the rotating drum and fall, cause boxes and bags to break up. The agitation helps eliminate cold spots. Sterilization involves pre-vacuum and post-vacuum cycles. The units are controlled by a touch-screen programmable logic controller.

### Types of Waste Treated

See Section 11.3.2.2. The Tempico Rotoclave can also treat pathological waste, contaminated animal carcasses, quarantine waste, raw pulp, and confidential documents.

### Range of Capacities

Model	Internal drum volume (m <sup>3</sup> )	Cycle time	Capacity (liter/hr)
1050-H1	0.65	45 minutes	870
1070-H1	0.73	45 minutes	970
1125-G1	1.78	55 minutes	1940
1250-G1	3	55 minutes	3270
1500-D1	5.89	60 minutes	5890
1500-DS1	7.3	60 minutes	7300
2500-D1	11.8	60 minutes	11800
2500-DS2	14.7	60 minutes	14700

Tempico also manufactures the very large K series Rotoclaves such as the 7' x 20' vessel (2.1 m diameter x 6 m long) for large central treatment facilities.

### Pathogen Destruction

See Section 11.3.2.4. The system achieves greater than 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### Emissions and By-Products

See Section 11.3.2.5.

### Operation

Medical waste bags and boxes are loaded into the drum using a hands-free automatic loader. 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. 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 reduced waste volume to about 80%.

### Installation

The equipment requires a concrete pad, steam, electricity, water, and compressed air.

### Maintenance

See Section 11.3.2.8.

### Job Potential

The Rotoclave requires an operator and is fully automated. Job potential is low.

### Locations where Technology is in Operation

There are more than a hundred Rotoclave units worldwide including American Samoa, Canada, Latvia, Mexico, United Kingdom and United States.

### Cost Estimates

See Section 11.5.3.

### Special Features

Tempico offers integrated scale and automatic loading systems, stainless steel conveyor systems, reusable carts, as well as single-stage and two-stage heavy-duty grinders. In addition to domestic and international sales, the company also supplies large units for regional waste treatment centers.

**Parameters for Specification**

Required capacity, electrical specifications, accessories

**Photographs**



L-R: Models 1050-H1, 1250-G1, and 1500-DS1

**Vendor Information**

Tempico was formed in 1990 and installed the first Rotoclave at a hospital in 1992. Since then, units have been sold worldwide.

**Contact Information**

Tempico, Inc.  
 1700 West Church Street, Suite C  
 Hammond, LA 70401  
 USA  
 Tel.: +1 (985) 429-9929  
 Fax: +1 (985) 429-9740  
 Email: tempico@tempico.com  
 www.tempico.com

**12.3 CONTINUOUS STEAM TREATMENT SYSTEMS**

12.3.1 BIOSAFE ENGINEERING

**Type of Technology**

Continuous steam treatment system

**Process Description**

BioSafe Engineering’s STI Medical Waste System is basically composed of an automatic waste bin dumper, hopper, internal shredder, sterilizing/conveying tube, flash-off section and output duct. The heart of the system is the tube which is inclined upwards and has an internal auger. The auger turns slowly and carries the shredded waste up the tube while steam is injected both through the auger shaft and inside the tube to sterilize the waste. The flash-off section removes the moisture. The system can operate 24 hours a day.

**Types of Waste Treated**

See Section 11.3.3.2. The STI Medical Waste System can handle pathological waste and destroy confidential documents.

**Range of Capacities**

Model	Capacity (lbs/hr)	Capacity (kg/hr)
STI 300 PPH	300	140
STI 600 PPH	600	270
STI 1000 PPH	1000	450

STI 2000 PPH	2000	910
STI 3000 PPH	3000	1400
STI 4000 PPH	4000	1800

### Pathogen Destruction

See Section 11.3.3.4. Tests conducted between 1995 and 1997 showed that the technology achieves greater than 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus*.

### Emissions and By-Products

See Section 11.3.3.5.

### Operation

Typically, the operator rolls the cart into the machine, pushes one button, and walks away. The process controller loads the waste into the hopper where a negative pressure is maintained by drawing air through a high efficiency particulate air (HEPA) filter. Hypochlorite solution can be sprayed to reduce odors. After the lid closes automatically, the waste in the hopper is pushed into a heavy-duty shredding unit by a ram. Shredded material enters a rotating auger conveyor where low-pressure steam is introduced through multiple ports maintaining the temperature in the conveyor between 96 to 115°C. Downstream of the conveyor is a dehydration section wherein a steam jacket increases the temperature and steam is flashed off through a vent at the very end of the conveyor and through a condenser; this causes the waste to dry off. The decontaminated waste exits the conveyor into a self-contained compactor or roll-off container for transport to a landfill. The heavy-duty shredder reduces waste volume up to 90%

### Installation

Installation of the equipment requires a steam source, electricity, sewer, ventilation and communications (e.g., Ethernet or phone line).

### Maintenance

See Section 11.3.3.8. The shredder cutters last between 900 to 1350 tonnes of waste before they are replaced. The shredder is designed to simplify the replacement of cutters.

### Job Potential

The STI system requires an operator and is fully automated. Job potential is low.

### Locations where Technology is in Operation

Dozens of STI units are found in commercial treatment plants in Australia, England, Ireland, Northern Ireland, and United States.

### Cost Estimates

See Section 11.5.3.

### Special Features

Weatherproof models are available for outdoor installation. The equipment can be constructed with a floor-level or dock-mounted entry. BioSAFE Engineering can provide waste carts, training, and service contracts.

### Parameters for Specification

Required capacity, electrical specifications, accessories

### Photographs



L-R: Models STI 300 PPH, 1000 PPH and 4000 PPH

### **Vendor Information**

In the mid-1990s, Sterile Technologies Industries introduced the continuous steam treatment system ChemClav combined with chemical disinfection. As the technology evolved, chemical disinfection was found to be unnecessary due to the efficacy of the steam treatment unit. The first unit was installed in 1995 and has since processed more than 135,000 tonnes of waste. The technology is sold by BioSafe Engineering.

### **Contact Information**

BioSAFE Engineering, LLC  
485 Southpoint Circle Building 200  
Brownsburg, IN 46112  
Tel.: +1 317-858-8099  
Fax: +1 317-858-8202  
Email: [info@biosafeengineering.com](mailto:info@biosafeengineering.com)  
[www.biosafeengineering.com](http://www.biosafeengineering.com)

## 12.3.2 ERDWICH

### **Type of Technology**

Continuous steam treatment system

### **Process Description**

The sterilization system TWIN-STER is modular and uses expandable plant components, which enable Erdwich to manufacture sterilization plants for different requirements and individual customer needs. The basic system is the TWIN-STER 2500. The treatment temperature is from 121°C - 140°C but temperatures of 150°C and higher are possible if desired. The system has a waste bin lifter and tipping device, hopper, heavy-duty shredder, buffer container, double-jacketed sterilization chamber with a double-lock slide system at the output end, steam generator, closed solid screw systems for conveying waste, discharge housing that can fit of waste containers of 1100 liters, a double-chamber filtration system for odor control, and operating control panel.

### **Types of Waste Treated**

See Section 11.3.3.2.

### **Range of Capacities**

The TWIN-STER 2500 has a capacity of 250 kg per hour. Other units can be designed according to customer needs.

### **Pathogen Destruction**

See Section 11.3.3.4.

### **Emissions and By-Products**

See Section 11.3.3.5.

### **Operation**

The operating steps are as following: (1) charging (about 1.5 minutes) – the waste container is placed in a balance and after the load is registered and the rolling gate closed, the lift and tilting mechanism dumps the

waste into the hopper; (2) shredding (5 – 15 minutes depending on the waste material) – after the lid is closed, a hydraulic device pushes the waste into the cutting gear of the shredder; (3) buffering – a screw conveyor transports the shredded waste into the buffer container which is used to regulate the volume of waste fed into the chamber; (4) charging and sterilization – the shredded waste is conveyed by another screw into the sterilization chamber (about 5 – 10 minutes), the entry gate closed, and steam is introduced into the chamber which is kept at the pre-set temperature for a given time, after which the chamber is depressurized; (5) discharge (about 10 minutes) – the chamber's output gate is opened and another screw transports the waste into bins in a discharge unit for final disposal.

### **Installation**

The equipment requires electricity, process water, ventilation and drain.

### **Maintenance**

See Section 11.3.3.8.

### **Job Potential**

The TWIN-STER requires an operator and is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

Erdwisch shredders are found in many countries. The TWIN-STER was developed in Germany.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Erdwisch provides an optional housing with a high-speed rolling gate integrated into the hopper.

### **Parameters for Specification**

Required capacity, electrical specifications, accessories

### **Photographs**



L-R: Lift and tilting mechanism with shredder and hopper, sterilization chamber, screw conveyor and discharge unit

### **Vendor Information**

Erdwisch has more than 30 years experience in the manufacture of shredding machines and industrial recycling plants for processing and treatment of hazardous waste and recovery of materials.

### **Contact Information**

ERDWICH Vertriebs GmbH  
Kolpingstrasse 8 - D-86916 KAUFERING  
Postfach 65 - D-86912 Kaufering  
Germany  
Tel.: (+49) 08191-9652-0  
Fax: (+49) 08191-9652-16  
Email: [infoline@erdwisch.de](mailto:infoline@erdwisch.de)  
[www.erdwisch.de](http://www.erdwisch.de)

### 12.3.3 LOGMED

#### **Type of Technology**

Continuous steam treatment system

#### **Process Description**

The LogMed GT series sterilizers are comprised of a feed hopper, shredder, treatment screws, built-in steam generator, discharge isolation valve, discharge tube, and programmable logic controllers. During the sterilization cycle, the waste is tumbled by the rotating screws back to the shredder to ensure exposure to steam. After completion of the cycle, the treatment screw reverses to transport the treated waste into the discharge tube. The largest model (GT 500) does not circulate the waste back into the shredder. Instead, the treatment screw is sealed by isolation valves and the temperature and pressure are increased to a pre-determined value for a set time. At the end of the cycle, the steam is vented, the isolation valve at the discharge end opens, and the treated waste is discharged into a container. Waste volume is reduced to about 20%.

#### **Types of Waste Treated**

See Section 11.3.3.2. Other models using similar technology are used for food waste.

#### **Range of Capacities**

Model	Capacity (kg/hr)
GT 100	100
GT 300	300
GT 400	400
GT 500	500

#### **Pathogen Destruction**

See Section 11.3.3.4.

#### **Emissions and By-Products**

See Section 11.3.3.5.

#### **Operation**

The waste in reusable containers is placed inside the feed hopper either manually or by using the optional semi-automatic feed system. Once the waste is in the hopper, the door to the feed system is closed and the sterilization process is started by the operator through the automatic control system. The waste is then shredded and transported into the treatment screws. After shredding, the operator can refill the feed hopper an additional two times before starting the sterilization cycle. Conditions in the treatment screws are controlled by the PLC-based control system. After the sterilization cycle, the steam is vented and the waste is discharged for disposal.

#### **Installation**

The technology requires electricity, water, ventilation and drain.

#### **Maintenance**

See Section 11.3.3.8. The equipment has an automatic, thermal decontamination process prior to maintenance.

#### **Job Potential**

The LogMed requires an operator and is automated. Job potential is low.

#### **Locations where Technology is in Operation**

The LogMed technology is licensed in Belgium, England, France, Germany, Luxemburg and Netherlands.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

An option for the GT-500 is a liquid sterilization system that takes excess liquid from the feed end of the treatment screw for separate sterilization. The LogMed can be designed as a mobile unit.

### **Parameters for Specification**

Required capacity, electrical specifications, accessories

### **Photographs**



L-R: LogMed 400 closed, LogMed 400 with outer covering removed

### **Vendor Information**

LogMed was founded in 2004. The company operates a treatment facility for specific waste (medical waste, airline catering, etc.) and synthetic diesel oil production for energy generation. The business areas of LogMed Technology GmbH involve the Logmed (for treatment of problematic waste and 20% volume reduction), Logfood (for treatment of catering waste), and Logmed®+PLUS+ (which involves a synthetic oil process).

### **Contact Information**

LogMed GmbH  
Brehnaer Str. 6  
D - 06188 Landsburg  
Germany  
Tel.: +49 34602 4031100  
Fax: +49 34602 4031111  
www.logmed.de  
info@logmed.dem

LogMed Cooperation GmbH  
Daniel-Vorländer-Straße 8  
D – 06120 Halle (Saale)  
Tel.: +49 (0) 345-4780-230  
Fax: +49 (0) 345-4780-233  
www.logmed-coop.de

## 12.3.4 MICLO

### **Type of Technology**

Continuous steam treatment system

### **Process Description**

The Miclo Log 100 is a continuous steam treatment system that entails automated feed, internal shredding, continuous steam exposure in a rotating auger, automated monitoring, and release of treated waste into a bin. The technology is comprised of a cart lifter/dumper, hopper, internal shredder, hydraulic ram to push the waste through the shredder, an inclined rotating auger where waste is exposed to steam under pressure, isolation doors at both ends of the auger, boiler, water softener, air compressor, and a system to decontaminate the liquid from the bottom of the auger. The waste is exposed to steam at 138°C and 3.6 bars for 15-18 minutes. Due to shredding, compaction and release of moisture, the system achieves about an 80% volume reduction and 10% mass reduction.

### **Types of Waste Treated**

See Section 11.3.3.2.

### **Range of Capacities**

The hopper has a capacity of 1100 liters. The Log 100 models range from 100 to 500 kg per hour.

### **Pathogen Destruction**

See Section 11.3.3.4. All evacuated air is treated before being released.

### **Emissions and By-Products**

See Section 11.3.3.5.

### **Operation**

The waste in 660 to 1100 liter containers is fed by a cart lifter and dumper into the hopper of the system. After the contents of the cart are dumped into the hopper, the lid is closed and the process begins. The auger is heated by injection of steam from a boiler. The process from loading to the ejection of waste takes about 1 hour. The technology is highly automated and data can be downloaded. The system can be operated 24 hours by a few people.

### **Installation**

The technology requires electricity, water, ventilation and drain. Miclo provides an integrated system that includes all the major components.

### **Maintenance**

See Section 11.3.3.8.

### **Job Potential**

The Log 100 is automated and requires a few people for 24 hour operation. Job potential is low.

### **Locations where Technology is in Operation**

Miclo works with NSC Environment of the NSC Group which has a sales network in 5 continents.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Miclo offers many types of shredders and grinders, remote monitoring and diagnostics.

### **Parameters for Specification**

Required capacity, electrical specifications

### **Photographs**



L-R: Log 100, hopper-shredder section, motor and isolation valve at the end of the auger

### **Vendor Information**

Miclo Environnement is located in the region of Mulhouse in France. The company has 30 years of experience in the field of grinding and compaction, as well as the shredding of infectious waste. They are also involved in

composting services, crushing of bulky industrial waste, waste transfer stations, on-site and remote monitoring, and telemetry systems for equipment diagnostics.

### **Contact Information**

Miclo Environnement  
1 Rue Pierre PFLIMLIN  
ZA Actipolis 3  
68390 Sausheim  
France  
Tel: 33 (0)3 89 31 68 50  
Fax: 0033 (0)3 89 61 99 87  
Email : nmiclo@wanadoo.fr  
<http://www.miclo-environnement.fr/>

## **12.4 BATCH MICROWAVE TECHNOLOGIES**

### 12.4.1 METEKA

#### **Type of Technology**

Batch microwave

#### **Process Description**

The Meteka system uses electricity to generate microwave energy which in turn transforms moisture into steam thereby sterilizing the waste. The system uses puncture-proof, reusable containers (“Meditainer” containers) which are transported using trolleys (“Meditrans” transport trolleys) and fit directly into the microwave sterilization device (“Medister”).

#### **Types of Waste Treated**

See Section 11.3.4.2. The Meteka system treats typical infectious waste stream such as microbiological waste, needles, syringes, dressing and waste from the wards, as well as liquid infectious waste, laboratory waste, dialysis waste, and waste from blood banks.

#### **Range of Capacities**

Model	Capacity (liters)
Medister 10	8
Medister 20	20
Medister 60	30
Medister 160	60
Medister 360 and 360-2	60

The Medister 360 and 360-2 are intended for highly infectious waste including waste from genetic engineering research.

#### **Pathogen Destruction**

See Section 11.3.4.4.

#### **Emissions and By-Products**

See Section 11.3.4.5.

#### **Operation**

The waste is placed in the pedal-operated Meditainers (reusable containers). When full, the Meditainer is transported in the Meditrans trolley. The microwave-proof heat-resistant Meditainer is then removed from the trolley and placed directly inside the front-loading Medister unit. The operator uses the integrated touch panel to start the disinfection cycle which runs automatically. Data is electronically stored and documentation is printed at the end of each cycle.

### **Installation**

The technology requires electricity and regular tap water.

### **Maintenance**

See Section 11.3.4.8.

### **Job Potential**

The Meteka system requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

The Meteka system is used in more than 20 countries including Bulgaria, Croatia, Czech Republic, Ecuador, England, Ethiopia, India, Indonesia, Iran, Germany, Greece, Latvia, Lithuania, Malaysia, Montenegro, Nigeria, Philippines, Poland, Romania, Russia, Serbia, and Turkmenistan.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

As an option, the Medister can print labels at the end of each cycle for marking the waste bag. The Medister can also be equipped with a built-in weighing scale and a special software can be provided to display data on a PC. Meteka also makes the Medister 560 Continuous Flow Sterilization Device for contaminated wastewater

### **Parameters for Specification**

Required capacity, electrical specifications, accessories

### **Photographs**



L-R: Medister 10 (desktop unit), Medister 60, Medister 360-2, Meditainers and Meditrans trolleys

### **Vendor Information**

METEKA GmbH was founded by Dr. Helmut Katschnig in 1987. The Medister 160 HF-Waste Disinfection Device was first used in 1991 in Austria and the small desktop Medister 10 was launched in 1993. Meteka started exporting the units in 1994. The Medister 360 was introduced in 2001 along with the Medister 560 wastewater treatment system. Meteka is certified according to ISO/EN 9001:2008 and ISO/EN 14001:2009.

### **Contact Information**

METEKA GmbH  
Viktor-Kaplan-Straße 7  
A 8750 Judenburg  
Austria  
Tel.: (+43)3572 / 85 166  
Fax: (+43)3572 / 85 166-6  
Email: [info@meteka.com](mailto:info@meteka.com)  
[www.meteka.com/index\\_en.php](http://www.meteka.com/index_en.php)

12.4.2 SINTION

### **Type of Technology**

Batch microwave

**Process Description**

The Sintion is a microwave system that uses electricity to generate microwave energy which in turn transforms moisture into steam thereby sterilizing the waste. The Sintion 1.1 is a small batch system that can be installed almost anywhere. The microwave unit has a vacuum system to remove air and increase steam penetration. A smaller desktop model, MicroSin, is also available.

**Types of Waste Treated**

See Section 11.3.4.2. The Sintion can handle synthetic materials (tubes, syringes, bottles, etc.), metals (needles), bandages, glass, agar plates, linens, paper, etc. as well as liquids up to 10 liters.

**Range of Capacities**

Model	Capacity (liters per cycle)
MicroSin	42
Sintion 1.1	103

The MicroSin handles about 20 liters of waste per hour. The Sintion has a treatment cycle of 10 to 30 minutes and can treat 210 liters per hour.

**Pathogen Destruction**

See Section 11.3.4.4. The Sintion is capable of achieving a 5 log<sub>10</sub> reduction of *Geobacillus stearothermophilus* and other microbiological indicators.

**Emissions and By-Products**

See Section 11.3.4.5.

**Operation**

The waste is placed loosely in a bag and filled up to 600 mm in height. The lid of the device is opened and the filled bag is placed through the opening at the top. One waste bag is treated at a time. For the first load of the day, a preheat cycle is used. For subsequent loads, the lid is closed and the operator pushes the “Operate” button and the device runs automatically. At the end of the cycle, an audible signal sounds and the display indicates that the waste can now be removed for disposal.

**Installation**

The technology requires electricity, deionized water, and a drain.

**Maintenance**

Maintenance is simple and involves cleaning the filter at the bottom of the boiler, checking the microwave seal in the lid, and cleaning surfaces and the disinfection chamber.

**Job Potential**

The Sintion requires an operator and is automated. Job potential is low.

**Locations where Technology is in Operation**

There are more than 100 Sintion units in use worldwide, including Austria, Bosnia & Herzegovina, Bulgaria, Czech Republic, Greece, Lithuania, Serbia in Asia, Europe, and Central and South America.

**Cost Estimates**

See Section 11.5.3.

**Special Features**

Sintion also provides three different sizes of shredders (ShredTion, MicroShred and MegaShred) for use with one or more microwave units.

**Parameters for Specification**

Required capacity, electrical specifications, accessories

### Photographs



L-R: Sinton 1.1, MicroSin (desktop unit)

### Vendor Information

The Sinton was developed by Dr. Wolfgang Moshammer and has been marketed since 1995.

### Contact Information

CMB Maschinenbau & Handels GmbH  
Concept Strasse 1  
8101 Gratkorn  
Austria  
Tel.: +43 (0)3124 / 22150 - 0  
Fax: +43 (0)3124 / 22150 - 210  
Email: [cmb@christof-group.at](mailto:cmb@christof-group.at)  
[http://www.sinton.at/en/cmb/sinton\\_3](http://www.sinton.at/en/cmb/sinton_3)

## 12.4.3 STERIFANT-STERIVAL

### Type of Technology

Batch microwave

### Process Description

The Sterifant is a modular microwave system that uses an energy module for producing steam, compressed air and cooling; a base module to control one or more microwave sterilization chambers and record data on a printer; extension modules; and special bins or containers. A container, placed in each module, is heated by a microwave generator to a temperature programmed by the operator. After steam treatment, the waste is shredded and compacted while drawing off any liquids. The dry sterile waste is reduced in volume up to 80%. A proprietary deodorizer is added to avoid odors. The shredder has a self-cleaning cycle after use. The system had on-board diagnostics. The polycarbonate bins are stackable and reusable an average of 100 times. Ten modules can also be incorporated into a truck for mobile treatment.

### Types of Waste Treated

See Section 11.3.4.2. The Sterifant can handle plastics, bandages, all types of textiles, body parts, syringes, needles, lancets, scalpels, bone screws, nails and glass.

### Range of Capacities

Each module is designed to treat a 60 liter container (about 12 kg of waste per container). At a sterilization temperature of 136°C, the cycle time ranges from 25-35 minutes.

### Pathogen Destruction

See Section 11.3.4.4. The Sterifant system achieves a 4 Log<sub>10</sub> reduction or greater.

### Emissions and By-Products

See Section 11.3.4.5.

### Operation

The 60-liter containers are placed in foot-operated wheeled stands. Waste is collected in the container. When full, the container lid is sealed using a clamp ring forming a hermetic seal. The container and stand can be moved around and sealed containers can be stacked. Each container is then placed in the sterilization module. At the start of the cycle, a hollow needle is lowered into the lid to puncture the bung seal and a washer around the needle forms a pressure seal. About 2 liters of water and steam at 140°C are injected into each container and then the microwave generator of each module heats the contents to temperatures of 95°C, 105°C, 121°C, or 136°C as selected by the operator. The system also employs a vacuum and pressurized atmosphere to ensure steam penetration. Waste can then be placed in a stand-alone shredder.

The mobile unit has a retractable platform which handles ten containers at a time. After treatment, the bins are transferred to an integral shredder on the side of the truck. An automatic arm lifts each bin and empties the contents into the shredder. This is followed by compaction at 80 bars pressure.

### **Installation**

The technology requires electricity, water, and a drain.

### **Maintenance**

See Section 11.3.4.8.

### **Job Potential**

The Sterifant requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

There are at least 27 units in Europe, 10 units in South America and 6 units in Asia. For example, the technology has been approved in France, Germany, Hungary, Kuwait, Portugal and the UK. Sterifant has offices in Europe, Middle East, Asia, South Africa, and South America.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Sterifant-Sterival system is available as a stationary or mobile unit. The special containers are stackable and shipped 48 containers per standard EU pallet.

### **Parameters for Specification**

Required capacity, stationary or mobile design, electrical specifications, accessories

### **Photographs**



L-R: Stationary unit, mobile unit, polycarbonate container

### **Vendor Information**

The Sterifant was developed in Germany and was approved in 1995 by the Robert Koch Institute of the German Ministry of Health.

### **Contact Information**

Sterifant Vertriebs GmbH  
12, rue Jean Engling, L-1466

Luxembourg  
 Tel.: +352-43 22 22,  
 Fax: +352-42 60 59  
 Email: sterilux@pt.lu

## 12.5 CONTINUOUS MICROWAVE TECHNOLOGIES

### 12.5.1 AMB ECOSTERYL

#### Type of Technology

Continuous microwave system

#### Process Description

The AMB Ecosteryl Microwaves Disinfection System combines internal shredding and microwave energy to heat healthcare waste to about 100°C. Microwaves are generated by one or two oven boxes each containing six 2 kW magnetrons (microwave generators). The shredded waste, which is reduced to less than 20 mm pieces, is held at the disinfection temperature for an hour by means of a computer control that includes a touch screen, monitoring and robotics. The stainless steel unit is fully automated. The residue is a dry shredded waste reduced by 80% in volume.

#### Types of Waste Treated

See Section 11.3.5.2. The equipment is used for waste contaminated with infectious agents and waste from hepatology, isolation units, surgery, obstetrics and gynecology departments, etc. as well as sharps waste.

#### Range of Capacities

Model	Capacity (kg per hour)
Ecosteryl 75	Up to 100
Ecosteryl 125	Up to 175
Ecosteryl 250	Up to 300

Ecosteryl 75 and 125 are intended for in situ treatment at a hospital. Ecosteryl 250 is for a central treatment facility.

#### Pathogen Destruction

See Section 11.3.5.4. Tests by the Institut Pasteur de Lille show a Log<sub>10</sub> 5 reduction of *Bacillus subtilis*.

#### Emissions and By-Products

See Section 11.3.5.5.

#### Operation

A waste bin (660 to 770 liters) is placed in an automated waste bin lifter and dumper assembly which automatically weighs the container and dumps the contents into the hopper. After the lid closes, a hydraulic arm pushes the waste into the shredder. The shredder has an automatic reverse feature to prevent blocking. An internal screw transports the shredded waste through one (Ecosteryl 75 and 125) or two (Ecosteryl 250) microwave ovens. At the end of the screw, the waste falls into a 500 liter holding tank with resistance heaters to maintain disinfection temperatures for a set time, after which the waste is transported by a discharge screw into a large container for disposal.

#### Installation

Technology installation takes only about two days including start-up and training of operators. The technology does not need steam or water.

#### Maintenance

See Section 11.3.5.8. The average life span of the internal shredders is about 1500 tonnes of processed waste.

#### Job Potential

The AMB systems require an operator and are fully automated. Job potential is low.

#### **Locations where Technology is in Operation**

AMB Ecosteryl has a presence in France and several European countries, the Maghreb countries (North Africa), South Africa, South America and Russia, overseas French territories, the Middle East and Asia.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

The technology uses a four-shaft shredder with a 20 mm screen.

#### **Parameters for Specification**

Required capacity, electrical specifications

#### **Photographs**



L-R: Ecosteryl 75, 125 and 250

#### **Vendor Information**

The AMB (Ateliers Mécaniques du Borinage) group is a private family group created in 1947 to design and manufacture machinery for the extraction industries. The company subsequently moved into the field of recycling, recovery and processing of metals and waste in general. AMB is certified ISO 9001. The Ecosteryl 250 was approved in 2006 by the French Ministry of Health while the Ecosteryl 125 was approved in 2008. The company has representatives in Belgium, Canada, China, Greece, India, Italy, Libya, Morocco, Nigeria, Pakistan, Russia, Sri Lanka, Syria, South Africa and Switzerland.

#### **Contact Information**

AMB  
Avenue Wilson 622  
B - 7012 Mons  
Belgium  
Tel.: +32 65 82 26 81  
Fax: +32 65 82 47 98  
Email : amebo@skynet.beat  
www.ecosteryl.net

### 12.5.2 MICRO-WASTE

#### **Type of Technology**

Continuous microwave system

#### **Process Description**

The Micro-Waste Disinfection System combines internal shredder with a moist heat disinfection system using steam and microwave energy. There are six or eight 1.4 kW microwave generators with individual PLC controls. The unit is self-contained in an all-weather steel enclosure that can be installed indoors or outdoors. The system has a programmable logic controller with a digital touch screen, which can be monitored in real-time off-site by operations management.

### Types of Waste Treated

See Section 11.3.5.2.

### Range of Capacities

Micro-Waste offers two models: MW-250S and MDS-2481. Capacity is about 800 kg per hour. The MDS-2481 has thicker shredder cutters, a different size screen, and no holding section for a higher throughput.

### Pathogen Destruction

See Section 11.3.5.4. Periodic testing is done using *Bacillus atrophaeus* spores.

### Emissions and By-Products

See Section 11.3.5.5. Air emissions pass through a HEPA filter.

### Operation

A cart scale documents the weight of the waste. The operator loads waste using the control panel which lifts the waste cart and dumps the contents into the hopper. Waste falls onto the counter-rotating shredder cutters. The shredder has an adjustable screen. The shredded waste is exposed to steam and heated by the microwave generators as it is transported by a conveyor screw. Model MW-250S has a holding tank and a discharge screw that discharges the treated waste into a container or solid waste compactor.

### Installation

Installation can be done in as quickly as a few hours.

### Maintenance

See Section 11.3.5.8. The shredder assembly is designed on a trolley which allows the entire shredder to be replaced in less than 6 hours.

### Job Potential

The Micro-Waste system requires an operator and is fully automated. Job potential is low.

### Locations where Technology is in Operation

The Micro-Waste technologies are found in the United States.

### Cost Estimates

See Section 11.5.3.

### Special Features

Micro-Waste can do remote monitoring to facilitate troubleshooting and software upgrades.

### Parameters for Specification

Required capacity, electrical specifications

### Photographs



L-R: Model MW-250S, Model MDS-2481

### Vendor Information

Micro-Waste Corporation began as a private entity in 1989 to sell, service, and maintain the ABB Sanitec system. The company designed and manufactured its own microwave system around 2005. Micro-Waste also provides carts, cart lifters, and tippers to hospitals, medical waste transportation and management companies.

#### **Contact Information**

Micro-Waste Corporation  
3006 SE Loop 820  
Fort Worth, TX 76140  
USA  
Tel.: +1-817-370-2426  
Email: TABollinger@Micro-Waste.com  
<http://www.micro-waste.com>

#### 12.5.3 SANITEC

##### **Type of Technology**

Continuous microwave system

##### **Process Description**

The Sanitec Microwave Disinfection System combines internal shredder, steam injection and microwave energy to heat waste to 95-100°C. The entire unit is delivered in a self-contained, all-weather steel enclosure that can be installed indoors or outdoors. The system has an on-board processor that continuously monitors and controls the system.

##### **Types of Waste Treated**

See Section 11.3.5.2. It can treat blood and blood products, dialysis waste, human and animal tissues, body parts, limbs, animal carcasses, biological waste, needles, syringes and other sharps waste, research waste, laboratory specimens, surgery waste, pathology and histology samples, waste contaminated with HIV/AIDS and hepatitis, isolation waste, cultures, IV bags and tubing, gloves, gowns and waste contaminated with trace amounts of chemotherapeutic agents.

##### **Range of Capacities**

The Sanitec treats 810 kg per hour and can be for in situ treatment at large hospitals or for central treatment facilities.

##### **Pathogen Destruction**

See Section 11.3.5.4. A periodic test is done using *Bacillus atrophaeus* spores to validate microbial inactivation.

##### **Emissions and By-Products**

See Section 11.3.5.5.

##### **Operation**

The waste is put in large carts and placed in the loading assembly, which automatically lifts and dumps the contents into the hopper while air is pulled through HEPA and activated carbon filters. After the lid is shut, the waste is ground by a two-shaft shredder and falls into a holding tank. A large stainless steel screw conveys the waste through six industrial magnetrons (microwave generators). The waste is heated by both microwave energy and injected steam. At the end of the screw, the shredded waste falls into a holding tank to ensure sufficient time at the disinfection temperature. A second screw discharges the waste to a large bin, compactor or roll-off container. An optional secondary shredder can be placed at the end of the discharge screw for fine shredding of needles and syringes or for further size reduction, if desired.

##### **Installation**

Installation requires only a standard 480 VAC electric line and standard water hookups for the steam generator. No drain is needed since there is no wastewater. Installation can be completed within two days, and units can be easily relocated.

### **Maintenance**

See Section 11.3.5.8.

### **Job Potential**

The Sanitec system requires an operator and is fully automated. Job potential is low.

### **Locations where Technology is in Operation**

The first Sanitec system was installed in 1990. Sanitec units are in operation in many states in the United States, as well as in Brazil, S. Korea, Philippines and other countries. An estimated 500 tons per day of healthcare waste are treated by Sanitec units worldwide.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The computer control includes a strip chart that provides a permanent record of the process parameters.

### **Parameters for Specification**

Required capacity, electrical specifications

### **Photographs**



L-R: Cart automatically loaded into the Sanitec system, two Sanitec systems operating side-by-side

### **Vendor Information**

The technology was originally developed in the late 1980s by Asea Brown Boveri and was subsequently taken over by Sanitec, Inc. (New Jersey, USA) which began manufacturing the system in 1990. Since then, the system has been installed worldwide.

### **Contact Information**

Sanitec  
4535 W. Valerio Street  
Burbank, California 91505  
USA  
Tel.: +1 (818) 565-5566  
Fax: +1 (818) 565-0035  
Email: [info@sanitecind.com](mailto:info@sanitecind.com)  
[www.sanitecind.com/Home.html](http://www.sanitecind.com/Home.html)

## **12.6 FRICTIONAL HEAT TREATMENT SYSTEMS**

### **12.6.1 NEWSTER**

#### **Type of Technology**

Frictional heat treatment system

#### **Process Description**

The Newster technology utilizes frictional heating supplemented by resistance heaters to heat the waste up to about 150°C while shredding it into a dry powder. The sterilization process is also aided by the addition of sodium hypochlorite. A high-speed rotor operating at two speeds—1300 to 2800 rpm—is used. The first part of the treatment employs moist heating by steam generated by the rotor causing the waste to reach a temperature of 100°C. The steam and other vapors generated pass through heat exchangers and filters to condense steam and filter the air before being released to the environment. When all the fluids have evaporated, the waste continues to be heated to dry superheated conditions. The waste is kept above 135°C up to 150°C for several minutes to achieve sterilization. The whole process takes place at atmospheric pressure. The residue is an odorless, dry product resulting in an average 70-75% volume reduction and 20-25% mass reduction. The system uses a programmable logic controller.

### **Types of Waste Treated**

See Section 11.3.6.2.

### **Range of Capacities**

Model	Capacity	
	Liters per cycle	Kg per hour
Newster 5	100	15
Newster 10	130	30

A typical cycle is 30 minutes.

### **Pathogen Destruction**

See Section 11.3.6.4.

### **Emissions and By-Products**

See Section 11.3.6.5.

### **Operation**

After the waste is fed into the system, the operator starts the motor at a low gear. After several minutes, the machine goes into the higher gear and continues to rotate until all the moisture is released and the waste reaches 120°C. The heaters are then turned off but the waste is allowed to increase in temperature to about 150°C. The motor is then put on a low gear and water is added to cool the waste to 95°C. After waiting a short period to allow the water to evaporate, the waste is allowed to discharge for about two minutes. At the end of the cycle, the controls are turned off.

### **Installation**

Installation requires electrical connections, water supply, drain, and vent for the vapor. Newster provides examples of installation layouts.

### **Maintenance**

See Section 11.3.6.8. Newster provides daily, monthly, quarterly, semi-annual and annual maintenance procedures.

### **Job Potential**

The Newster system requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

As of January 2011, there were 223 Newster units in operation in Albania, Azerbaijan, Belarus, Brazil, Bulgaria, Croatia, Dominican Republic, Egypt, Estonia, Greece, Hungary, Iran, Italy, Kazakhstan, Paraguay, Poland, Romania, Russia, and Tunisia.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Newster offers waste containers, waste bin washer boxes with germicidal UV, and wastewater treatment and air purification systems.

**Parameters for Specification**

Required capacity, electrical specifications, accessories

**Photographs**



L-R: Newster 10, Newster 5, close-up of the treated waste

**Vendor Information**

Newster Srl was formed in 1996. It is certified by UNI EN ISO 9001 2008. Newster’s partner, Tecno Service First Srl (Serravalle, Republic of San Marino), deals with research and development. In addition to Italy, Newster has affiliates and subsidiaries in Belarus, Brazil, Bulgaria, Croatia, Dominican Republic, Egypt, Estonia, Greece, Hungary, Iran, Kazakhstan, Paraguay, Poland, Romania, Russian Federation, Tunis and Uruguay.

**Contact Information**

Newster Srl  
 Via Montalbano 1377/V  
 47842 San Giovanni in Marignano (RN)  
 Italy  
 Tel: ++378 (0549) 960576  
 Fax ++378 (0549) 960585  
 Email: info@newster.sm; market@newster.sm  
 www.newster.sm

12.6.2 OMPECO

**Type of Technology**

Frictional heat treatment system

**Process Description**

The OMPeco technology combines frictional heating and internal shredding to produce a dry, odor-free waste with a 70% volume reduction and 30% mass reduction. The process takes place in about 30 minutes. The larger units consist of an automatic waste bin loader, sterilization chamber or cell containing rotor blades at the bottom, valves for water injection and waste discharge, pumps for vapor extraction, filter and condenser, and a heat exchanger. Vapors and condensate are filtered. The system is fully enclosed and controlled by a programmable logic controller.

**Types of Waste Treated**

See Section 11.3.6.2. The OMPeco Converter H series handles a wide range of waste including sharps waste, bandages, diapers, gloves, catheters, probes, small plastic and glass bottles, filters, food waste from isolation wards, cultures, surgical waste including not easily recognizable anatomical parts, small animal carcasses, gowns, glass, metal, paper, pillows, etc. The Converter can handle large volumes of blood. Other models treat municipal, animal and maritime waste.

**Range of Capacities**

Model	Capacity
-------	----------

	Liters per cycle	Kg per hour
Converter H10	100	10
Converter H25	200	25
Converter H75	700	75
Converter H200	1500	200
Converter H500	4000	500
Converter H1500	11000	1500

The H series is for infectious waste applications. The MO and NV series is for municipal/organic and naval applications.

### Pathogen Destruction

See Section 11.3.6.4. The microbial inactivation efficacy of OMPeco Converter was tested at the Second University of Naples during a trial period in the hospital of Massa (Tuscany region) Stabilimento Ospedaliero della Fondazione Toscana Gabriele Monasterio Ricerca Medica e di sanità Pubblica, Ospedale del Cuore. The microbial inactivation efficacy of the technology is periodically validated using  $10^6$  spores of *Geobacillus stearothermophilus* placed in a special pocket in the sterilization cell.

### Emissions and By-Products

See Section 11.3.6.5.

### Operation

The OMPeco Converter goes through seven operational steps: loading, frictional heating, evaporation at 100°C, further heating to 151°C, sterilization at 151°C and ambient pressure for 3 minutes, cooling to 40°C, and unloading as the rotor discharges the treated waste.

### Installation

Installation requires electricity, water supply and vent for the vapor.

### Maintenance

See Section 11.3.6.8. In the event of a malfunction, the machine has the capability of injecting sodium hypochlorite disinfectant prior to conducting repairs. The main items for replacement are the shredder blades and filter which generally last for 1.5 years.

### Job Potential

The OMPeco Converter is fully automated and one operator can control one or more machines. Job potential is low.

### Locations where Technology is in Operation

As of August 2011, there were about 62 OMPeco Converter units in operation in Bosnia, Botswana, Brazil, Bulgaria, Canada, Chile, China, Croatia, France, Italy, Kazakhstan, Mexico, Netherlands, Romania, Russia, South Africa, Spain, Tunisia, Turkey, Ukraine, and Venezuela.

### Cost Estimates

See Section 11.5.3.

### Special Features

Converter Models H75, H200, H500 and H1500 include an automatic waste loader. The basic OMPeco Converter uses a cooler which can be a radiator design or a cooling tower design. OMPeco also offers the MO series for municipal and organic waste (including food waste, farming waste, food processing waste, slaughterhouse waste), and the NV series for cargo ships, cruise ships and other naval applications.

### Parameters for Specification

Required capacity, electrical specifications, accessories

### Photographs



L-R: OMPeco Converter Models H10, H75, H200 and close-up of treated waste

### Vendor Information

OMPeco is the environmental division of Officine Meccaniche Pejrani srl (OMP), a company founded in 1973 by Luigi Pejrani for the manufacture of mechanical parts for industrial and agricultural vehicles. OMP is ISO 9001 and ISO 14001 certified. The OMPeco Converter was invented by Gianpiero Morgantini of OMPeco's research and development sector. The Converter was patented and developed in 2001. The company has representatives in Morocco, Namibia, and South Africa.

### Contact Information

Ompeco Ecotechnology (OMPeco)  
Officine Meccaniche Pejrani srl  
Strada Moncalieri 99/36  
Frazione Tetti Caglieri  
10048 Vinovo  
Torino, Italy  
Tel.: +39 011 99 35 111  
Fax: +39 011 99 35 133  
Email: [info@ompeco.com](mailto:info@ompeco.com)  
[www.ompeco.com](http://www.ompeco.com)

## 12.7 DRY HEAT TREATMENT SYSTEMS

### 12.7.1 DEMOLIZER

#### Type of Technology

Dry heat treatment

#### Process Description

The Demolizer II is a small table-top device that uses dry heat to treat healthcare waste. The waste is heated from 177°C to a maximum of 200°C. It is quiet and cool to the touch during operation. The Demolizer II uses a unique Sharps and Red Bag Collection system. The Collector is comprised of a puncture and leak resistant container with a closable lid. The Sharps Collector has a plastic spinning lid which melts in the Demolizer II and encapsulates the sharps waste for disposal. The Demolizer unit continually self-monitors and controls the process.

#### Types of Waste Treated

See Section 11.3.7.2. The Demolizer II treats sharps and infectious wastes from doctors' offices, dental clinics, small health facilities, school clinics, nursing homes, first-aid stations, and veterinary clinics.

#### Range of Capacities

The Demolizer II has a 3.8 liter capacity with a process cycle time of 2.5 hours.

#### Pathogen Destruction

See Section 11.3.7.4. The technology achieves greater than a 6 Log<sub>10</sub> reduction of *Bacillus subtilis* spores, *S. aureus*, Methicillin resistant *S. aureus*, *E. coli*, *P. aeruginosa*, *C. albicans*, *M. fortuitum*, *M. bovis*, *M. phlei*, and *Giardia spp.*

### **Emissions and By-Products**

See Section 11.3.7.5. Tests of air from the unit showed no bio-aerosols released.

### **Operation**

The Demolizer II has a simple three-step operation: (1) place the Sharps or Red Bag Collector into the Demolizer II; (2) Select either the Sharps or Red Bag Waste option from the Demolizer II control menu; and (3) Push the start button. The unit then operates automatically. Two labels automatically print out at the end of the process. One label can be attached to a log book for permanent documentation while the other can be affixed to the container prior to disposal as regular waste.

### **Installation**

No special assembly is required. The unit simply plugs into a standard electrical outlet.

### **Maintenance**

See Section 11.3.7.8. The life expectancy of the equipment is 12 to 15+ years.

### **Job Potential**

The Demolizer II is automated and intended for small facilities. Job potential is low.

### **Locations where Technology is in Operation**

Demolizer and Demolizer II units are in use throughout the United States.

### **Cost Estimates**

Capital cost is estimated at USD 6995.

### **Special Features**

The Demolizer II is used with 3.8 and 4.7 liter Sharps or Red Bag Collectors. The unit has a dual air filtration system to prevent odors and the release of bio-aerosols. It automatically restarts itself and completes the treatment process in the event of a power outage. Monthly process data can be downloaded from the internal computer using an analog phone line.

### **Parameters for Specification**

Electrical specifications, accessories including number of disposable Collectors

### **Photographs**



L-R: Demolizer II unit, Sharps Collector with spinning lid, Red Bag Collector being placed in the Demolizer II unit, treated container being discarded with label

### **Vendor Information**

The Demolizer was originally introduced by DOCC (New York) and received approvals for use in the United States in the early 1990s under Thermal Waste Technologies, Inc. The Demolizer technology was acquired by BioMedical Technology Solutions, Inc. (BMTS) in 2005 and was enhanced with advanced quality control, hardware and remote diagnostics. BMTS introduced the Demolizer II in late 2006.

### **Contact Information**

BioMedical Technology Solutions, Inc.  
9800 Mount Pyramid Court, Suite 250

Englewood, Colorado 80112  
USA  
Tel.: +1 (303) 653-0100  
Fax: +1 (303) 653-0120  
Email: sales@bmtscorp.com  
www.bmtscorp.com/index.htm

## 12.7.2 STERIGERMS

### **Type of Technology**

Dry heat treatment

### **Process Description**

The Sterigerms is a compact unit that uses electricity and a piston to compact the waste between 4.5 and 5.5 bar pressure and heat the waste up to 150°C for 20 minutes. The cycle time including loading, heating and cooling is less than an hour. The equipment can be stationary or mounted on wheels. The treated waste is in the form of a flat compact disk which can be discarded as regular waste. Volume is reduced by about 85-90%.

### **Types of Waste Treated**

See Section 11.3.7.2. The Sterigerms treats contaminated dressings, syringes, catheters, used needle containers, sharp instruments and other infectious wastes from hospitals, clinics, home health care, pathology laboratories, medical offices, transfusion centers, and civilian or military ships.

### **Range of Capacities**

Model	Capacity (liters per cycle)
Sterigerms 12	12
Sterigerms 60	60

The Sterigerms has a total process cycle of 55 minutes.

### **Pathogen Destruction**

See Section 11.3.7.4. Microbial inactivation tests were conducted by the Université de Montpellier.

### **Emissions and By-Products**

See Section 11.3.7.5.

### **Operation**

The operational steps are simple: Waste including sharps containers are placed in a Steribag which is closed and is placed in the Sterigerms unit. The lid is closed and the operator starts the cycle using the touch screen. The waste is compressed and heated to 150°C and kept at that temperature for about 20 minutes, after which the waste is allowed to cool. When the waste, now in the shape of a compressed disk, is cool, it is ejected and discarded in a regular waste bin.

### **Installation**

Installation only involves plugging the equipment to a standard electrical outlet. No water supply or drain is needed.

### **Maintenance**

See Section 11.3.7.8. Maintenance is simple.

### **Job Potential**

The Sterigerms is automated and intended for small facilities. Job potential is low.

### **Locations where Technology is in Operation**

The Sterigerms technology is used by the French Navy and is marketed in Europe.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

A higher temperature can be programmed if desired. Documentation can be provided by a Windows-based software available from Sterigerms, with access codes for users and administrators. A bar code system is available as an option. The units can be fitted with anti-skid wheels.

### **Parameters for Specification**

Electrical specifications, accessories including number of disposable Steribags

### **Photographs**



L-R: Sterigerms 12, Sterigerms 60, Steribag with sharps containers placed in the Sterigerms, treated waste in the form of a sterile compressed disk

### **Vendor Information**

Sterigerms France was founded in 2004. The Sterigerms 12 and Sterigerms 60 technologies were approved in France in 1999 and 2000, respectively.

### **Contact Information**

Sterigerms  
BP 27  
26600 La Roche de Glun  
France  
Tel.: + 33 [0]4 90 11 37 37  
Fax: + 33 [0]4 90 11 37 30  
Email: [contact@sterigerms.com](mailto:contact@sterigerms.com)  
[www.sterigerms.com](http://www.sterigerms.com)

## **12.8 INCINERATORS AND RELATED TECHNOLOGIES**

### **12.8.1 ADVANCED COMBUSTION SYSTEMS**

#### **Type of Technology**

Dual-chamber controlled air incineration

#### **Process Description**

The Advanced Combustion Systems' HSW Series incinerator is a modular, dual-chamber, controlled air incinerator with an automatic ram feeder and built-in hydraulic power, primary and secondary burners, monolithic refractory lining, air injection system, automatic ash removal, and fully automatic PLC controls. The secondary chamber provides a two-second residence time at 1000°C minimum temperature. The air pollution control system consists of the following: a two-stage saturator-quencher, condenser-absorber, venturi scrubber, multi-stage entrainment separator, wet electrostatic precipitator, and stack with optional heating for plume suppression.

#### **Types of Waste Treated**

See Section 11.3.8.2.

**Range of Capacities**

Model	Capacity (kg per hr)
CA 500HSW	110
CA 750HSW	170
CA 1000HSW	230
CA 1250HSW	280
CA 1500HSW	340
CA 1750HSW	400
CA 2000HSW	450
CA 2500HSW	570
CA 3000HSW	680
CA 4000HSW	910

**Pathogen Destruction**

See Section 11.3.8.4.

**Emissions and By-Products**

See Section 11.3.8.5. The air pollution control system is able to reduce dioxin releases to 0.0023 ng TEQ/dscm, particulates to 0.004 gr/dscf, hydrogen chloride to 0.23 ppm, sulfur dioxide to 0.1 ppm, lead to 0.024 mg/dscm, mercury to 0.0061 mg/dscm, and cadmium to 0.00042 mg/dscm.<sup>198</sup>

**Operation**

See Section 11.3.8.6.

**Installation**

See Section 11.3.8.7.

**Maintenance**

See Section 11.3.8.8.

**Job Potential**

The ACS incinerators are automated and require an operator. Job potential is low.

**Locations where Technology is in Operation**

The ACS incinerators can be found in Afghanistan, Canada, Iraq, Lebanon, Mexico, Saipan, United States, and other countries.

**Cost Estimates**

See Section 11.5.3.

**Special Features**

Continuous emission monitoring systems and data acquisition systems are available as options. The company sells ash vacuum systems, ash carts, waste cart tipplers, automatic loaders, advanced port air injection systems, and waste heat recovery with a scrubber and activated carbon bed.

**Parameters for Specification**

Required capacity, electrical specifications, air pollution control specifications, optional accessories

**Photographs**

---

<sup>198</sup> Based on tests conducted on a 90 kg/hr ACS incinerator with a scrubber at Washington State University.



L-R: Model CA-1500, Model CA-750, gas cleaning scrubber, ash cart

### Vendor Information

Advanced Combustion Systems was founded in 1973 and has over 700 combustion systems worldwide. ACS has a 2,500 square ft. corporate office and 10,000 square ft. manufacturing plant in Bellingham, Washington. The company also sells liquid injection systems, melting furnaces, waste oil incinerators, controlled air rotary burners, municipal solid waste incinerators, and crematories.

### Contact Information

Advanced Combustion Systems  
 1999 Alpine Way  
 Bellingham, WA 98226  
 USA  
 Tel.: +1 360.676.6005  
 FAX: +1 360.647.9439  
 Email: INFO@ACS-ACS.COM  
 www.acs-accs.com

## 12.8.2 ATI INCINERATEURS MULLER

### Type of Technology

Dual-chamber pyrolytic incineration

### Process Description

ATI makes two types of incinerators: C.P. series which are small dual-chamber incinerators ranging from 5 to 100 kg/hr, and the H.P. series which range from 150 to 1000 kg/hr. The H.P. type has an automatic loader, automatic waste tipper, primary and secondary chambers with corresponding burners, and heat recovery boiler. The secondary chamber operates at 1100°C and uses a high-turbulence vortex oxygen injection system. The air pollution control system can be a wet or dry process and is composed of wet or dry sorbent injection scrubber systems, ceramic filter, induced draft fan, and a stack. ATI has its own software system to monitor, control and view operating parameters.

### Types of Waste Treated

See Section 11.3.8.2. The ATI incinerators can handle infectious waste, pathological waste, sharps, pharmaceutical waste, genotoxic waste, chemical waste, and low level radioactive waste.

### Range of Capacities

Model	Capacity (kg per hr)
CP5	5
CP10	10
CP15	15-20
CP30	30-40
CP50	50-60
CP100	100-120
HP500	150
HP750	200

HP1000	250
HP1250	350
HP1500	500

**Pathogen Destruction**

See Section 11.3.8.4.

**Emissions and By-Products**

See Section 11.3.8.5. The ATI incinerators with their gas cleaning system meet EU emission limits under the European incineration standard Directive EU 76/2000.

**Operation**

See Section 11.3.8.6.

**Installation**

See Section 11.3.8.7.

**Maintenance**

See Section 11.3.8.8.

**Job Potential**

The ATI incinerators are automated. Job potential is low.

**Locations where Technology is in Operation**

ATI has installed at least 32 incinerators that meet the emission limits under the EU Directive. Over 700 units are found in 55 countries including Algeria, Angola, Bahrain, Belgium, Cameroon, Central Africa, Congo, France, Gabon, Germany, Guadeloupe, Guyana, Guinea, Libya, Martinique, Mauritania, Mauritius, Morocco, Netherlands, New Caledonia, Nigeria, Oman, Poland, Portugal, Saudi Arabia, Senegal, Syria, Tahiti, Taiwan, Togo, Tunisia, Ukraine, UAE, and Vietnam.

**Cost Estimates**

See Section 11.5.3.

**Special Features**

The company offers an optional radiator to cool the gases after the secondary chamber. The stack has a platform for gas sampling and analysis of emissions. The incinerator can be locally controls via a console or remotely monitored and controlled. ATI technicians can assist via a hotline or the Internet.

**Parameters for Specification**

Required capacity, electrical specifications, air pollution control specifications, optional accessories

**Photographs**



L-R: Models CP100, HP1000, neutralizing dry scrubber and filter

**Vendor Information**

ATI Incinerateurs Muller was founded in 1930. The company also manufactures incinerators for industrial hazardous waste, sludge waste, animal carcass and all other kinds of organic waste, as well as human corpse cremation furnaces and painting pickling furnaces.

### **Contact Information**

ATI Incinerateurs Muller  
Le Bourg  
45420 Champoulet  
France  
Tel.: +33 (0)2 38 29 29 02  
Fax: +33 (0)2 38 31 94 59  
Email: [info@ati-incinerateurs.com](mailto:info@ati-incinerateurs.com)  
[www.ati-incinerateurs.com](http://www.ati-incinerateurs.com)

### 12.8.3 BIC SYSTEMS

#### **Type of Technology**

Rotary kiln incineration

#### **Process Description**

The BIC medical waste incinerator is a rotary kiln incinerator with a ram feed and waste bin lifter powered by hydraulics, guillotine fire doors and hopper lids powered by compressed air, an inclined cylindrical primary combustion chamber that operates above 1000°C using natural gas or diesel burners, a static post-combustion chamber with a residence time greater than two seconds and a burner to maintain 1100°C, and a mechanism for automatic and continuous removal of bottom ash. The company makes both co-current and counter-current rotary kilns with heat recovery. Their counter-current rotary kilns allow for better control of flue gases. The air pollution control system includes a cooling chamber, a dry scrubber (venturi-type absorption with a residence time exceeding two seconds) using sodium bicarbonate to neutralize acid gases and activated carbon for heavy metals and dioxins, a baghouse filter, induced draft fan, and stack. BIC also offers wet scrubbers using sodium hydroxide solution, semi-wet scrubbers using lime, cyclones and electrostatic precipitators to meet emission limits.

#### **Types of Waste Treated**

See Section 11.3.8.2.

#### **Range of Capacities**

BIC Group manufactures rotary kilns in a wide range of sizes according to customer needs—from small (100-200 kg/hr), medium (300-600 kg/hr), large (750 to 1400 kg/hr) to very large (2000 to 5000 kg/hr) incinerators.

#### **Pathogen Destruction**

See Section 11.3.8.4.

#### **Emissions and By-Products**

See Section 11.3.8.5. BIC can design its scrubbing systems to meet USEPA or EU emission limits.

#### **Operation**

See Section 11.3.8.6.

#### **Installation**

See Section 11.3.8.7.

#### **Maintenance**

See Section 11.3.8.8.

#### **Job Potential**

The BIC incinerators are automated and require an operator. Job potential is low.

#### **Locations where Technology is in Operation**

Various types of BIC incinerators can be found in Belgium, Cote D'Ivoire, Czech Republic, France, Germany, Saudi Arabia, Singapore, Slovakia, Tanzania, Thailand, UAE, UK, and Vietnam.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

Heat recovery can be in the form of a heat recovery boiler, steam turbine or co-generation plant depending on the type of scrubber is used. The company also offers remote access and SMS alarms.

#### **Parameters for Specification**

Required capacity, electrical specifications, air pollution control systems, accessories

#### **Photographs**



L-R: Co-current rotary kiln, counter-current rotary kiln (900 kg/hr)

#### **Vendor Information**

BIC Group (formerly the Belgian Incinerator Company) was founded by Jean Vandewalle in Belgium in 1972. The initial technologies were moving grate incinerators and rotary kiln systems. In 1999, the company expanded to Asia and Africa. BIC Systems has service centers in the Asia Pacific and Middle Eastern regions. BIC also makes incineration plants for hazardous chemical waste, paint sludge, explosives, and liquids. They are ISO 9000:2000 and ISO 14001 certified.

#### **Contact Information**

BIC Group  
Bijenstraat 30,  
B-9051 Gent (SDW)  
Belgium  
Tel.: +32 9 221 71 56  
Fax: +32 9 221 48 65  
Email: [info@bic.be](mailto:info@bic.be)  
[www.bic.be](http://www.bic.be)

#### 12.8.4 CONSUTECH

#### **Type of Technology**

Dual-chamber stepped hearth controlled air incineration

#### **Process Description**

Consutech's Consumat are modular controlled air incinerators. The primary chamber is a stepped hearth operating at about 790°C. The secondary chamber operates at about 1000°C and designed to have a residence time as required by regulations. The Consumat has a heat recovery boiler and ash handling system. The air pollution control system consists of a quench chamber with atomizing water spray nozzles, dry scrubber with activated carbon injection, a wet scrubber if required, a vortex mixing chamber, baghouse fabric filter, induced

draft fan, and stack. Consutech designs incinerators for intermittent (8 and 16 hour) operation and continuous (24 hour) operation.

**Types of Waste Treated**

See Section 11.3.8.2.

**Range of Capacities**

Consutech manufactures 33 models ranging in size from about 34 kg/hr to over 100 tonnes per day.

**Pathogen Destruction**

See Section 11.3.8.4.

**Emissions and By-Products**

See Section 11.3.8.5.

**Operation**

See Section 11.3.8.6.

**Installation**

See Section 11.3.8.7.

**Maintenance**

See Section 11.3.8.8.

**Job Potential**

The Consumat incinerators are automated and require an operator. Job potential is low.

**Locations where Technology is in Operation**

Thousands of Consumat incinerators have been installed worldwide since 1965.

**Cost Estimates**

See Section 11.5.3.

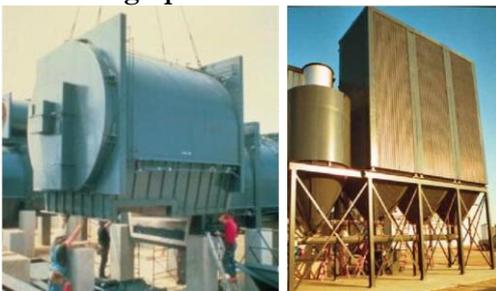
**Special Features**

The carbon injection system pneumatically conveys activated carbon powder into the scrubber system to reduce dioxins. A silo or hopper is used to store the dry sorbent or carbon. The primary and secondary chambers are independently controlled.

**Parameters for Specification**

Required capacity, electrical specifications, air pollution control systems, accessories

**Photographs**



L-R: Consutech incinerator under construction, dry scrubber-baghouse filter gas cleaning system

**Vendor Information**

Consutech is a privately held company with manufacturing facilities in Richmond, Virginia, USA. The company has been manufacturing the Consumat waste combustion technology and air pollution control equipment for 35 years. Consutech also makes municipal and industrial incinerators.

### **Contact Information**

Consutech Systems, LLC  
PO Box 15119  
Richmond, Virginia 23227  
USA  
Tel.: +1 (804) 746 – 4120  
Fax: +1 (804) 730 - 9056  
Email: mail@consutech.com  
www.consutech.com

### 12.8.5 HAFNER

#### **Type of Technology**

Rotary kiln incineration

#### **Process Description**

The Hafner system is a rotary kiln incinerator with a secondary chamber, heat exchanger or heat recovery boiler, and multi-step flue gas cleaning. The mobile Hafner incinerator is modular and assembled from eight shipping containers. The following describe the eight containers: (1) furnace operating at 900°C to 1200°C with feeder and continuous ash discharge, (2) secondary chamber with afterburner operating at 1200°C to 1300°C and a minimum two-second residence time, (3) flue gas quencher with heat exchanger, (4) flue gas cleaning using a Teflon-coated fabric filter, (5) flue gas cleaning using dry absorption by injection of soda, coke and bicarbonate, (6) flue gas cleaning by catalysis to remove NO<sub>x</sub> and dioxins/furans, (7) controls, and (8) emergency generator and compressor. The stationary Hafner incinerator is also modular and uses 22 modules. The furnace operates at 950°C to 1000°C, and the secondary chamber at 1050°C with a minimum residence time of two seconds. In addition to the dry absorption system, the stationary incinerator can also use a wet wash prior to catalytic treatment.

#### **Types of Waste Treated**

See Section 11.3.8.2.

#### **Range of Capacities**

The Hafner system can be assembled with eight modules to handle 7 tonnes per year, or with 22 modules to handle 3.5 tonnes per hour or 25000 tonnes per year.

#### **Pathogen Destruction**

See Section 11.3.8.4.

#### **Emissions and By-Products**

See Section 11.3.8.5. The Hafner system can achieve 0.1 ng TEQ/Nm<sup>3</sup> of dioxins and furans.

#### **Operation**

See Section 11.3.8.6. The basic procedures are waste charging, combustion in the rotary furnace, secondary combustion, heat recovery, flue gas cleaning, and emission monitoring.

#### **Installation**

See Section 11.3.8.7. Hafner provides installation, maintenance, management and training.

#### **Maintenance**

See Section 11.3.8.8.

### **Job Potential**

The Hafner incinerators are automated and require an operator. Job potential is low.

### **Locations where Technology is in Operation**

Hafner incinerators can be found in Austria, Croatia, Germany, Italy, and Venezuela. Its markets also include Asia and Eastern Europe.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The company can provide a modular grate system instead of a rotary kiln. Measured values are printed and stored in the computer memory.

### **Parameters for Specification**

Required capacity, electrical specifications, air pollution control systems, accessories

### **Photographs**



L-R: Hafner mobile rotary kiln incinerator, secondary chamber, stationary rotary kiln incinerator

### **Vendor Information**

The company was founded by Heinrich Hafner and is based in Italy.

### **Contact Information**

Hafner LLC  
Negrelli Street 5  
I-39100 Bolzano  
Italy  
Tel.: +39 0471 566 300  
Fax: +39 0471 566 301  
Email: [info@hafner.it](mailto:info@hafner.it)  
[www.hafner.it](http://www.hafner.it)

## 12.8.6 INCINCO

### **Type of Technology**

Reciprocating or riddling grate dual-chamber incineration

### **Process Description**

The Incinco incinerators are dual-chamber incinerators fuelled by oil, gas or LPG. The incinerators can be manually or automatically fed via auto feeder (ram loader) and can be supplied with an automatic bin tipper system. They have an ash grate and trolley for easy de-ashing and the larger units are fitted with reciprocating and riddling grates which can also incorporate a submerged ash conveyor allowing automatic ash removal. The secondary chamber has a full two-second residence time at temperatures in excess of 1400°C. The operation is automated.

### **Types of Waste Treated**

See Section 11.3.8.2.

### **Range of Capacities**

Incinco's hospital incinerators range in size from 25 kg/hr to over 2000 kg/hr.

### **Pathogen Destruction**

See Section 11.3.8.4.

### **Emissions and By-Products**

See Section 11.3.8.5. To meet emissions regulations, Incinco provides a range of flue gas cleaning equipment from wet scrubber systems to fully integrated ceramic pod dry filtration systems. Incinco also provides a full range of monitoring equipment for real time information on emissions. Some of the incinerators installed in developing countries do not have air pollution control devices capable of meeting the Stockholm Convention guidelines.

### **Operation**

See Section 11.3.8.6.

### **Installation**

See Section 11.3.8.7. The company provides installation, commissioning and training, and handles transport and shipping.

### **Maintenance**

See Section 11.3.8.8.

### **Job Potential**

The Incinco incinerators are automated and require an operator. Job potential is low.

### **Locations where Technology is in Operation**

Incinco has supplied 10,000 incinerators worldwide since 1922. Some are found in Algeria, Bangladesh, Ethiopia, Ghana, Iraq, Kosovo, Libya, Nigeria, Pakistan, Qatar, Seychelles, Sri Lanka, UK, and Vietnam.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Waste heat recovery systems provide either hot water or steam via a single or double pass tube boiler. Boilers are integrated within the overall unit structure and are commonly used as a method of heat reduction before gas cleaning.

### **Parameters for Specification**

Required capacity, electrical specifications, air pollution control systems, accessories

### **Photographs**



L-R: Incinco hospital incinerator, waste bin tipper and controls, hospital stack

### **Vendor Information**

Incinco is a kiln and incinerator manufacturer founded in 1922.

### **Contact Information**

Incinco Limited  
113-115 Codicote Road  
Welwyn  
Hertfordshire AL6 9TY  
United Kingdom  
Tel.: + 44 (0) 1438 821 000  
Fax: + 44 (0) 1438 820 888  
Email: enquiries@incinco.com  
www.incinco.com

#### 12.8.7 KUREHA

### **Type of Technology**

Rotary kiln incineration

### **Process Description**

The Kureha system is comprised of an automated waste feed system, rotary kiln with a secondary chamber, ash extraction system, a jet furnace with a high residence time, an efficient quenching tower capable of cooling the gases to below 80°C, neutralizing wet scrubber with a re-circulating alkali precipitation tank and wastewater treatment system, mist Cottrell wet electrostatic precipitator, induced draft fan, and stack.

### **Types of Waste Treated**

See Section 11.3.8.2. In addition to medical waste, Kureha incinerators can treat sludge containing corrosive chemicals, plastics, industrial solvents, residue industrial oils, and contaminated soils.

### **Range of Capacities**

Kureha incinerators are intended for large-scale processing at central treatment facilities.

### **Pathogen Destruction**

See Section 11.3.8.4.

### **Emissions and By-Products**

See Section 11.3.8.5. Kureha developed dioxin and carbon monoxide reduction systems in 1999 and 2003. They can achieve less than 0.1 ng TEQ/Nm<sup>3</sup> of dioxins and furans without the use of activated carbon.

### **Operation**

See Section 11.3.8.6.

### **Installation**

See Section 11.3.8.7.

### **Maintenance**

See Section 11.3.8.8.

### **Job Potential**

The Kureha incinerators are automated and require an operator. Job potential is low.

### **Locations where Technology is in Operation**

The Kureha incinerators are found in Japan where they operate medical waste incinerators processing around 1200 tonnes to 1600 tonnes per month.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

As an option, Kureha can provide dry scrubbers with active carbon and/or catalysts after controlling dioxins through their jet furnace.

### **Parameters for Specification**

Required capacity, electrical specifications, air pollution control specifications, optional accessories

### **Photographs**



L-R: Kureha incinerator, automatic loading for healthcare waste, air pollution control system showing scrubber and mist Cottrell electrostatic precipitator

### **Vendor Information**

Kureha Engineering and Kureha Ecology Management have provided waste treatment technologies since the 1970s. The parent Kureha Corporation was founded in 1944 and is involved in plastics, textiles, construction, plant engineering, environmental testing, real estate, trading of chemical products, and medical services.

### **Contact Information**

Kureha Engineering (Kureha Corporation)  
135 Ochiai, Nishiki Town  
Iwaki City, Fukushima Prefecture 974-8232  
Japan  
Tel.: (81)246-63-5150  
Fax: (81)246-63-6232  
Email: [etm-sec@kureha-eng.co.jp](mailto:etm-sec@kureha-eng.co.jp)  
[www.kureha-eng.co.jp](http://www.kureha-eng.co.jp)

## 12.8.8 PENNRAM

### **Type of Technology**

Dual-chamber stepped hearth controlled air incineration

### **Process Description**

The Pennram incinerator is a dual chamber, stepped hearth, controlled air incinerator with 2 to 4 steps and 1 to 4 ash transfer rams in the air-tight primary chamber and a secondary chamber with fully modulated air injection. Waste is fed by means of an automatic hydraulic loader designed for fully automatic operation. The primary chamber operates at about 816°C and the secondary chamber at 760 to 1093°C (depending on regulatory requirements) using natural gas, diesel oil, No. 6 fuel oil, or other fuels. The ash chute is partially submerged in a wet ash conveyor trough. As the ash is dumped into the ash chute, it dowsed in water and transferred by the automatic ash removal system to the ash container. The water in the ash trough provides an air-tight seal. The Pennram incinerator has multiple safety interlocks and alarms for safety. The air pollution control system is comprised of a wet scrubber and baghouse filter.

### **Types of Waste Treated**

See Section 11.3.8.2.

### **Range of Capacities**

Pennram's medical waste incinerators have capacities ranging from 25 kg/hr to 30 tons/day.

### **Pathogen Destruction**

See Section 11.3.8.4.

### **Emissions and By-Products**

See Section 11.3.8.5. Pennram can meet US EPA, EU and international emission limits.

### **Operation**

See Section 11.3.8.6. The operation is initiated by the operator pushing the "charge" push-button. The ram feeder is then set in motion by the closing of all charge interlocks, followed by the opening of the fire door, waste pushed into the primary chamber by the charge ram, retraction of the charge ram, closing of the fire door, and opening of the hopper lid for the next load. If the system has ash transfer rams, the rams cycle prior to the charge sequence.

### **Installation**

See Section 11.3.8.7.

### **Maintenance**

See Section 11.3.8.8. The life expectancy of Pennram incinerators is about 15 years.

### **Job Potential**

The Pennram incinerators are automated and require an operator. Job potential is low.

### **Locations where Technology is in Operation**

Different types of Pennram incinerators can be found in 50 countries including countries in Africa, North America, Caribbean and the Middle East.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Waste heat recovery could be done using a boiler, hot water heater, or air-to-air heat exchanger. Pennram also offers a skid-mounted turbine generator.

### **Parameters for Specification**

Required capacity, electrical specifications, air pollution control systems, accessories

### **Photographs**



L-R: Pennram medical incinerator, wet scrubber, wet ash conveyor, baghouse filter

### **Vendor Information**

Pennram Diversified Manufacturing Corporation was founded around 1995. It offers fixed modular systems, mobile self-contained skid mounted incinerators, and containerized incinerators. The company has contacts in Brazil, Ecuador, Nigeria and other countries.

### **Contact Information**

Pennram Diversified Mfg Corp  
PO Box 695  
Williamsport, PA 17703 0695  
USA  
Tel.: +1 (570) 327-2802  
Fax: +1 (570) 326-5650  
Email: pennram@pennram.com  
www.pennram.com/medical.html

## 12.8.9 PLANTEC

### **Type of Technology**

Vertical stoker type incinerator

### **Process Description**

A conventional stoker incinerator uses a system of grates to move the waste through different drying and combustion zones in the incinerator. The PLANTEC "Vertical Combustor" system configures the combustion zones vertically while supplying pre-heated air from the bottom. In this vertical configuration, the waste is deposited above the main combustion zone forming a thick waste layer. As the waste descends by its own weight, it is first dried, then partially pyrolyzed and carbonized due to the lower oxygen concentration in the top zones, then combusted and converted into ash, which falls to the bottom and is periodically discharged into a water-sealed ash conveyor. The gaseous by-products move upwards through a secondary combustion chamber to be further combusted with a residence time greater than two seconds. The plant can be installed with a boiler system for generating electricity or a hot water generator for thermal recycling.

### **Types of Waste Treated**

See Section 11.3.8.2. Healthcare waste with a calorific value greater than 700 kcal/kg (2,930 KJ/kg) can be incinerated. Healthcare waste is introduced into the incinerator in sealed plastic containers or carton boxes.

### **Range of Capacities**

The capacities of the Vertical Combustor furnaces range from 417 kg/hr to 4,167 kg/hr.

### **Pathogen Destruction**

See Section 11.3.8.4.

### **Emissions and By-Products**

See Section 11.3.8.5. PLANTEC uses a gas cooling process followed by a dry chemical reaction baghouse using slaked lime and/or activated carbon to meet US EPA and EU emission limits in Table 11.1. A wet scrubber is not needed.

### **Operation**

See Section 11.3.8.6. The operation entails: (1) charging of waste through an inclined waste feeder with a double damper using a conveyor or pit & crane system; (2) as the waste drops into the combustor, computer controls adjust operating parameters to maintain optimal conditions; (3) gaseous by-products pass through the flue gas cleaning system which is monitored and regulated by the computer controls; and (4) ash discharged from the bottom into the water-sealed conveyor under the furnace is automatically deposited into containers or specially designed ash pits, while fly ash from the baghouse is chemically stabilized and deposited into containers for disposal.

### **Installation**

See Section 11.3.8.7.

### **Maintenance**

Maintenance involves daily inspections, monthly inspections of water spray nozzles and conveyor chains, quarterly maintenance such as lubrication, and an annual maintenance including partial maintenance of refractory. The dry chemical reaction baghouse filters are replaced every five years.

### **Job Potential**

The PLANTEC incineration plant is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

The Vertical Combustors have been installed in Japan and Dubai, UAE.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Due to the very low air ratio and partial pyrolysis above the main combustion zone, the PLANTEC system adapts well to fluctuations in waste composition. Moreover, auxiliary fuel is used only during start-up.

### **Parameters for Specification**

Required capacity, waste composition and calorific value, annual number of operating days, utility specifications, emission limits, type of thermal recovery, construction schedule

### **Photographs**



L-R: Plant with two (50 tonnes per 24 hour) medical waste incinerators and power generation; plant with a 19.2 tonne per 24 hour incinerator

### **Vendor Information**

PLANTEC was formed in 1967 and has developed and delivered moving grate incinerators, vertical stoker type incinerators and flue gas cleaning equipment for 45 years. It has supplied 145 incineration plants. In 2009, PLANTEC entered into an alliance with Mitsubishi Corporation. The company is ISO9001:2008 certified.

### **Contact Information**

PLANTEC INC.  
1-6-17 Kyomachibori, Nishi-ku  
Osaka, 550-0003,  
JAPAN  
Tel: +81-6-6448-0141  
Fax: +81-6-6448-4370  
Email: [ptinfo@plantec-kk.co.jp](mailto:ptinfo@plantec-kk.co.jp)  
[www.plantec-kk.co.jp](http://www.plantec-kk.co.jp)

12.8.10 TECHTROL/INCOL

### **Type of Technology**

Dual-chamber stepped hearth controlled air incineration

### **Process Description**

The Techtrol clinical waste incinerator is a stepped hearth pyrolytic incinerator. The Techtrol system has a waste bin tipping system and hydraulically powered ram loader and vertical lifting door that work in unison with the combustion process. The combustion chamber has multiple steps with waste loading taking place at the highest step and each subsequent lower step in the hearth has an ash transfer ram to push the residue through the chamber and finally into the ash treatment zone. Ash can be discharged directly into closed bins. This design enables continuous operation during a 24 hour period with automatic ash removal. Temperatures in the chambers are controlled by burners using natural gas, LPG and fuel oil. An automatically controlled centrifugal fan provides pre-heated air through nozzles in the combustion chamber. The secondary chamber has a two-second residence time at 1000°C to 1200°C. The system uses PLC controls. The flue gases are cooled by a heat exchanger system with air blast cooling heat dissipater (or a heat recovery boiler). The air pollution control system is a dry scrubber using a neutralizing sorbent reagent and activated carbon followed by a filter unit with multiple elements, an induced draft fan and stack.

In addition to the Techtrol incinerator, Incol makes vertical primary chamber incinerators, rotary kilns, and crematories. Incol's air pollution control system is either a dry scrubber like that of Techtrol, a venturi wet scrubber with neutralizing liquid and wastewater treatment, and/or a catalytic gas cleaning system. The wet scrubber system includes a dual-stage quench system, injection of the neutralizing liquid, and particulate removal. Incol has also developed a system for mercury abatement.

**Types of Waste Treated**

See Section 11.3.8.2.

**Range of Capacities**

Techtrol Model	Capacity (kg per hr)
Pyrotec C150	150
Pyrotec C250	250
Pyrotec C500	500
Pyrotec C750	750
Pyrotec C1000	1000

Incol Model	Capacity (kg per hr)
PY 200	135
PY 450	300
PY 900	600
PY 1200	800
PY 2000	1350

**Pathogen Destruction**

See Section 11.3.8.4.

**Emissions and By-Products**

See Section 11.3.8.5. Particulate matter, carbon monoxide and oxygen are monitored by Techtrol. Additional monitors for nitrogen oxide, sulfur dioxide, hydrogen chloride and volatile organic compounds are also available, depending on regulatory requirements. Incol offers continuous monitoring of particulate matter/opacity, and up to seven gases including oxygen, carbon monoxide, nitrogen oxide, sulfur dioxide, hydrogen chloride, and hydrogen fluoride.

**Operation**

See Section 11.3.8.6. The six main steps in the operation are: preheat, burn cycle, automatic loading, burn down, cool down, and ash removal.

**Installation**

See Section 11.3.8.7.

**Maintenance**

See Section 11.3.8.8.

### **Job Potential**

The Techtrol and Incol incinerators are automated and require an operator. Job potential is low.

### **Locations where Technology is in Operation**

Different types of Techtrol incinerators can be found in Ascension Islands, Australia, Bangladesh, Cyprus, Egypt, Falkland Islands, Finland, Hong Kong, Jordan, Kenya, Libya, Macedonia, Malaysia, Nigeria, Northern Ireland, Norway, Saudi Arabia, Tanzania, UAE, UK, and Uganda. Incol has distributed thousands of Techtrol incinerator units and 800 Incol units in Latin America. Those units can be found in Argentina, Bolivia, Brazil, Columbia, Honduras, Paraguay, and Uruguay.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Both Techtrol and Incol make intermittent (up to 16 hours operation) and continuously operating incinerators.

### **Parameters for Specification**

Required capacity, type of incinerator (intermittent or continuous), electrical specifications, air pollution control systems, accessories

### **Photographs**



L-R: Techtrol Pyrotec clinical incinerator, Incol incinerator with scrubber, Incol heat recovery boiler and catalytic gas cleaning system

### **Vendor Information**

Techtrol began in 1985 and was based in Cheshire, UK. At the start of the 1990s, Techtrol moved to larger premises in Stockport. They now have about 8,000 square feet at our disposal. Techtrol is ISO 9001 and ISO 14001 registered. Incol S.A. is a private company in Argentina that began in the early 1990s and has an exclusive license to the Techtrol technology. Incol has offices in Argentina and Brazil.

### **Contact Information**

Techtrol Ltd  
Gregson Road  
Reddish  
Stockport, Cheshire  
SK5 7SS  
UK  
Tel.: +44 (0)161-476 6955  
Fax: +44 (0)161-476 2674  
Email: mailbox@techtrol.co.uk  
www.techtrol.co.uk

Incol Co SA.  
Chacabuco 4875, 1650, San Martin  
Gran Buenos Aires  
Argentina

Tel.: (54 11) 4768 7088 (Rot)  
 Fax: (54 11) 4767 6807  
 Email. info@incol.net  
 www.incol.net

## 12.9 ALKALINE HYDROLYSIS TECHNOLOGIES

### 12.9.1 BIORESPONSE

#### Type of Technology

Alkaline hydrolysis

#### Process Description

The technology uses a stainless steel tank and a basket. After the waste is loaded in the basket and into the sealed tank, alkali is added along with water. The contents are heated for a predetermined time period, after which the residues are removed or discarded. Bio-Response offers both a high-temperature system and lower cost low-temperature (Bio-Liquidator) system. Except for a discharge pump, their system does not use a pump for internal circulation (to avoid seal problems) and instead uses a propeller mixer under the basket.

#### Types of Waste Treated

See Section 11.3.9.2. The technology is designed for tissue wastes including anatomical parts, organs, placenta, blood, body fluids, specimens, human cadavers and animal carcasses. The process has been shown to destroy formaldehyde, glutaraldehyde, many chemotherapeutic agents, and prions. The low-temperature system is intended for pet crematories, farmers, abattoirs, animal shelters, etc.

#### Range of Capacities

Low-Temperature Model (diameter/depth, in inches)	Capacity (kg per cycle)
24/24	30
30/31	100
48/50	500
48/75	1000
72/40	1000
72/60	1500
Custom	Custom up to 4500

The low-temperature models have a total process cycle of 6 to 18 hours depending on the type and amount of tissue.

High-Temperature Model (diameter/depth, in inches)	Capacity (kg per cycle)
24/24	30
30/31	100
48/50	500
48/75	1000
72/40	1000
72/60	1500
Custom	Custom up to 4500

The high-temperature models have a total process cycle of 5 to 8 hours depending on the type and amount of tissue.

#### Pathogen Destruction

See Section 11.3.9.4. Alkaline hydrolysis can achieve Log<sub>10</sub> reductions of 7 to 9 of various microbiological indicators.

#### Emissions and By-Products

See Section 11.3.9.5.

### **Operation**

See Section 11.3.9.6 for a typical operation. The low-temperature models operate at 93°C and atmospheric pressure. The high-temperature models up to 150°C and 60 psig (4 bar gauge pressure).

### **Installation**

See Section 11.3.9.7.

### **Maintenance**

See Section 11.3.9.8.

### **Job Potential**

The Bio-Response technology requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

There are over 75 alkaline hydrolysis units installed by the president of the company (as WR2) from the late 1990s to mid-2000. The units are found in veterinary schools, university research labs, bio-safety levels 3 and 4 laboratories, pharmaceutical firms, agricultural institutions and government agencies in Canada, Ireland, United States, and other countries. Low-temperature units are found in Australia, United States and other countries.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The two smallest models have a manual feed of hydroxide. The larger models have a built-in load cell. The larger high-temperature models have a hydraulic locking lid. The company also makes mobile units.

### **Parameters for Specification**

Capacity, electrical specifications, accessories

### **Photographs**



L-R: Low-temperature unit showing steel basket, unit being tipped up for operation, test pig carcasses before treatment, bone residues after treatment

### **Vendor Information**

Bio-Response was founded in 2006 by Joe Wilson who had been president and CEO of WR<sup>2</sup>, the company that pioneered alkaline hydrolysis in the United States. Bio-Response has a network of associates worldwide including Australia, South America, Singapore, South Pacific, China, Europe, Canada, and the U.S. with peripheral agencies in many other countries. The company also makes high-temperature, thermo-chemical, chemical, continuous flow and under-sink effluent decontamination/liquid biowaste systems, as well as alkaline hydrolysis units for funeral disposition.

### **Contact Information**

Bio-Response Solutions, Inc.  
1298 E. US Hwy 136, Suite A  
Pittsboro, IN 46167  
USA

Tel.: +1 317-892-5200  
 Fax: +1 425-458-3194  
 Email: info@bioresponsesolutions.com  
 http://bioresponsesolutions.com

## 12.9.2 BIOSAFE ENGINEERING

### Type of Technology

Alkaline hydrolysis

### Process Description

BioSAFE Engineering offers the WR<sup>2</sup> tissue digester technology. The technology uses a steam-jacketed, insulated stainless steel pressure vessel with a manually or hydraulically clamped lid and a basket to contain the bone remnants. After the waste is loaded in the basket and into the sealed tank, alkali (sodium or potassium hydroxide) is added along with water. The contents are heated to elevated temperatures and pressures for a predetermined time period, after which the residues are removed or discarded. The system is fully automated; allowing unattended operation after the unit is loaded. The process results in up to 97% volume and mass reduction.

### Types of Waste Treated

See Section 11.3.9.2. The technology is designed for anatomical and pathological waste generated in healthcare and medical and veterinary schools; animal tissue and carcasses from biomedical and pharmaceutical research facilities; and government research and diagnostic facilities. The process has been shown to destroy formaldehyde, glutaraldehyde, and many chemotherapeutic agents. It has been approved for destruction of prions in Europe.

### Range of Capacities

	Capacity range (kg per cycle)
Low Pressure Small Lab Tissue Digester	15
Small Capacity Tissue Digester	14 to 27
Medium Capacity Tissue Digester	37 to 340
Large Capacity Tissue Digester	680 to 4336
Human Cadaver Water Resolution Unit	159

The total processing time is 5-8 hours depending on different variables. Digestion time is 3-4 hours for processing at a maximum temperature of 150°C, plus 2-4 hours for heat-up, cool down, rinsing, and draining. Examples of specific models are:

Model	Capacity (kg per cycle)
Lab-30	14
Lab-45	20
100-18-20	37
100-30-31	130
100-34-38	230

### Pathogen Destruction

See Section 11.3.9.4. Alkaline hydrolysis can achieve Log<sub>10</sub> reductions of 7 to 9 of various microbiological indicators.

### Emissions and By-Products

See Section 11.3.9.5. The process converts animal, human, and microbial tissues into a sterile, neutral, aqueous solution suitable for disposal to a sanitary sewer. Proteins, nucleic acids, and lipids of all cells and tissues, as well as infectious microorganisms, are converted into a solution of small peptides, amino acids, sugars, soaps, electrolytes, and salts of the hydrolysis products leaving behind the mineral constituents of bone and teeth which can be easily crushed and recovered as calcium phosphate powder (sterile bone meal).

### Operation

See Section 11.3.9.6. To begin the process, the vessel must be loaded with tissue and sealed by the operator. The operator then presses the START button on the touch screen and the cycle begins. After the operator has initiated the cycle, the digestion cycle runs completely unattended. A measured amount of alkali is pumped from a supply tank and process water is added based on tissue weight measured by the built-in load cells. The recirculation pump is turned on and the vessel contents are heated via a steam jacket and/or steam heating coils. When this cycle is complete, a cooling cycle lowers the temperature of the liquid and the unit is then drained.

#### **Installation**

See Section 11.3.9.7.

#### **Maintenance**

See Section 11.3.9.8.

#### **Job Potential**

The BioSAFE Engineering WR<sup>2</sup> technology requires an operator and is highly automated. Job potential is low.

#### **Locations where Technology is in Operation**

There are more than a hundred WR<sup>2</sup> units in use in Canada, United States and other countries. The first unit was installed in 1993 and is still in operation.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

BioSAFE designs can provide heating of the pressure vessel by direct steam injection or internal heating coils. Cooling water recovery tanks and pH reduction of the effluent by CO<sub>2</sub> injection are options. Tissue Digestors now use touch screen controls. BioSAFE also offers a small low-pressure model.

#### **Parameters for Specification**

Capacity, electrical specifications, accessories

#### **Photographs**



L-R: Tissue Digestors: low pressure small lab unit, medium capacity unit, large capacity unit, human cadaver unit; close-up of bone residues after treatment

#### **Vendor Information**

BioSAFE/WR<sup>2</sup> engineers have worked on tissue digester components and designs since 1992. BioSAFE/WR<sup>2</sup> has a staff of customer service representatives available 24 hours a day, 7 days a week. BioSAFE engineers are able to monitor remotely Tissue Digestors and can make process changes from their facility in Indianapolis. BioSAFE also makes mobile mass disposal Tissue Digestors, double-door pass-through Tissue Digestors for biosafety levels 3 and 4 bio-containment facilities, as well as effluent decontamination systems-Tissue Digester combined units.

#### **Contact Information**

BioSAFE Engineering, LLC  
485 Southpoint Circle, Bldg. 200  
Brownsburg, IN 46112

USA  
Tel.: +1 317-858-8099  
Fax: +1 317-858-8202  
Email: info@biosafeengineering.com  
www.BioSAFEengineering.com

### 12.9.3 PEERLESS WASTE SOLUTIONS

#### **Type of Technology**

Alkaline hydrolysis

#### **Process Description**

Peerless Waste Solutions D-series units are designed to treat pathological waste including laboratory research animals. The process uses potassium hydroxide as the reagent and is approved in the EU for the treatment of prion infected animals. The D-series units have steel vessels with heating/cooling coils, lids and baskets. They are designed to operate at low pressure and temperature, usually around 95°C and process times are generally around 20 to 24 hours. The end product is a liquid that has a pH of 9.5 to 11, a BOD of 50,000 to 100,000 and can be used as a fertilizer. This liquid can be handled by most sewerage treatment facilities.

#### **Types of Waste Treated**

See Section 11.3.9.2. The technology is designed for pathological waste such as tissue wastes, anatomical parts, and animal carcasses.

#### **Range of Capacities**

Model	Capacity (kg per cycle)
PWS Vet-55	45
PWS D-1 (two sizes)	7 and 14
PWS D-2	90
Larger custom models	Up to 180

The total process cycle is 20 to 24 hours.

#### **Pathogen Destruction**

See Section 11.3.9.4.

#### **Emissions and By-Products**

See Section 11.3.9.5.

#### **Operation**

The automated D-series models include controls automation to allow a simple one push-button operation with a preset timer to complete a full cycle, drain, and flush the unit without an operator.

#### **Installation**

See Section 11.3.9.7. No assembly is required; the units are fully factory-assembled and tested before shipping. The D-series units only require a standard electrical outlet, water supply, and a drain.

#### **Maintenance**

See Section 11.3.9.8.

#### **Job Potential**

The Peerless Waste Solutions D-series units require an operator and are intended for small facilities. Job potential is low.

#### **Locations where Technology is in Operation**

The technology is found in the United States.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

Units can be made with manual valves and controls or with a single push-button for simple operation. Units can be made with a stainless steel vessel and lid for a longer service life and are covered with ABS plastic covers for easy cleaning. The units come with casters so they can be moved to other locations.

### **Parameters for Specification**

Required capacity, electrical specifications, accessories

### **Photographs**



L-R: PWS D-2 unit, 66 kg of chicken before treatment, 3 kg of bones left after treatment

### **Vendor Information**

Peerless Waste Solutions manufactures alkaline hydrolysis units, effluent decontamination systems, and medical waste treatment systems. The company also makes a continuous steam treatment system for medical waste.

### **Contact Information**

Peerless Waste Solutions, LLC  
510 E. 40th Street  
Holland, MI 49423  
USA  
Tel.: 1-616-355-2800  
Fax: 1-616-355-2890  
Email: [sales@peerlesswaste.com](mailto:sales@peerlesswaste.com)  
[www.peerlesswaste.com](http://www.peerlesswaste.com)

## 12.9.4 PRI

### **Type of Technology**

Alkaline hydrolysis

### **Process Description**

PRI has two types of alkaline hydrolysis technologies: the Caustic Digester Unit and the Thermal Tissue Digester. The Caustic Digester process is a combination of water, caustic (alkali), and heat for alkaline hydrolysis to occur. As the caustic liquid is re-circulated, animal matter is converted to proteins then to amino acids with the exception of bones in one operation. PRI's Caustic Digester Units discharge a liquid with elevated BOD while bones, metallic objects and cellulose-based material remain in the basket. The Thermal Tissue Digester (TTD) uses agitation and heat to break down tissue with alkali. A high-torque low-speed rotor is used for agitation. The simple design does not require a basket handling system. The process can be designed to release a wet discharge to a sanitary sewer or a dry discharge in slurry form that solidifies upon cooling and can be disposed in a landfill.

### **Types of Waste Treated**

See Section 11.3.9.2. The technology is designed for tissue wastes including anatomical parts, and animal carcasses. PRI's Caustic Digester is compliant with EU, US, and other standards for the inactivation of prions and destruction of all known pathogens.

#### **Range of Capacities**

Since PRI is a custom engineering fabricating firm, it can manufacture alkaline hydrolysis systems with capacities ranging from 14 kg to 4500 kg per cycle.

#### **Pathogen Destruction**

See Section 11.3.9.4.

#### **Emissions and By-Products**

See Section 11.3.9.5.

#### **Operation**

See Section 11.3.9.6 for a similar operation.

#### **Installation**

See Section 11.3.9.7.

#### **Maintenance**

See Section 11.3.9.8.

#### **Job Potential**

The PRI technology requires an operator and is automated. Job potential is low.

#### **Locations where Technology is in Operation**

Alkaline hydrolysis units can be found in Canada, China, Germany, S. Korea, Malaysia, Spain, United States, and other countries.

#### **Cost Estimates**

See Section 11.5.3.

#### **Special Features**

The PRI technology prints out batch reports showing operating parameters and a pass-fail indication which is saved as a PDF file for documentation.

#### **Parameters for Specification**

Capacity, electrical specifications, accessories

#### **Photographs**



L-R: Caustic Digester Unit (CDU) with 36 kg capacity, CDU with 300 kg capacity, solidified mass from the CDU, Thermal Tissue Digester (TDU) 500

#### **Vendor Information**

Progressive Recovery, Inc. is a custom engineering fabricating firm specializing in modular heat transfer systems for liquid processing and sterilizing. PRI was founded in 1983 as designers and manufacturers of heat transfer,

fluid processing, modular equipment design and bio-containment systems with more than 2500 systems sold worldwide. Their 60,000 square foot manufacturing facility was built more than 15 years ago with an additional 18,000 ft<sup>2</sup> added more recently. The company also manufactures effluent decontamination systems.

#### **Contact Information**

Progressive Recovery, Inc.  
700 Industrial Drive  
Dupo, IL 62239  
United States  
Tel.: +1 (618) 286-5000  
Fax: +1 (618) 286-5009  
Email: dmarks@progressive-recovery.com  
www.pri-bio.com

### **12.10 CHEMICAL TREATMENT SYSTEMS**

#### **12.10.1 PIWS**

##### **Type of Technology**

Chemical treatment

##### **Process Description**

Positive Impact Waste Solutions manufactures the PIWS-3000 as a mobile or stationary unit. The technology uses a two-chamber grinding process and a dry inorganic (calcium oxide-based) chemical called Cold-Ster to disinfect the waste. While the waste is shredded, the dry chemical is simultaneously mixed with the waste. A mist of water is added to activate disinfection. The waste is pushed through the grinding process until small enough to pass from the top chamber to the bottom. In the bottom chamber, the waste is continually ground until the waste is small enough to be forced through the discharge auger. Grinding reduces waste volume by over 70%. The PIWS-3000 uses an on-board computer to monitor and control the process.

##### **Types of Waste Treated**

See Section 11.3.10.2.

##### **Range of Capacities**

The PIWS large mobile and stationary units treat over 900 kg per hour. The PIWS-3000 On-Site was developed for a healthcare facility and can process up to 180 kg per hour.

##### **Pathogen Destruction**

See Section 11.3.10.4. Microbial inactivation tests have shown a greater than 6 log<sub>10</sub> kill for *Bacillus atrophaeus* and *Geobacillus stearothermophilus*.

##### **Emissions and By-Products**

See Section 11.3.10.5. There is no wastewater discharge.

##### **Operation**

After the waste is emptied into the PIWS-3000 On-Site unit, the 30-minute process begins. The feed hopper captures the net weight of each load and the proper amount of Cold-Ster is added to the waste to be processed and is mixed while the waste is ground in the two stage grinding process. The waste is ground and mixed throughout the process and the processed material is conveyed out of the system by an auger directly into a general trash receptacle. As the material moves through the auger, a pH probe continuously monitors the processed waste to ensure that the pH of the outgoing waste is within limits. For each load, the exact time, weight and ending pH is captured by the computer and printed for documentation.

##### **Installation**

The PIWS-3000 On-Site unit requires only electrical power and water.

### **Maintenance**

See Section 11.3.10.8.

### **Job Potential**

The PIWS is highly automated. Job potential is low.

### **Locations where Technology is in Operation**

The PIWS-3000 has been operating continuously in the United States since 1997. It was first introduced internationally in Europe in 2001 and China in 2004. Units are operating in a number of locations throughout China. Patents have been obtained in Canada, China, France, Germany, Ireland, Italy, Korea, Mexico, Russia, Spain, Turkey, United Kingdom, and other countries.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

PIWS can assist in design and engineering.

### **Parameters for Specification**

Capacity, electrical specifications

### **Photographs**



L-R: Stationary installation, On-Site unit, mobile system

### **Vendor Information**

Positive Impact Waste Solutions, LLC is a privately held Delaware corporation based in Odessa, Texas. It offers custom manufacturing of medical waste processing equipment and oilfield equipment at its manufacturing facility in Odessa, Texas with over 20,000 square feet.

### **Contact Information**

Positive Impact Waste Solutions  
601 S. Pagewood  
Odessa, Texas 79761  
Tel.: +1 (432) 580-5885; US: +1 (888) 550-7497  
Fax: +1 (432) 580-6886  
Email: [solution@piwsinc.com](mailto:solution@piwsinc.com)  
<http://www.piwsinc.com>

12.10.2 STERIMED

### **Type of Technology**

Chemical treatment

### **Process Description**

The SteriMed simultaneously shreds, grinds, mixes and treats infectious waste in a Ster-Cid solution (a proprietary mixture of glutaraldehyde and quarternary ammonium compounds). After treatment, the material is discarded as conventional solid waste. The shredding, grinding and mixing of the waste is then initiated to expose all surfaces of the medical waste to the chemical solution during the 15-minute processing cycle. At the

end of each cycle, a valve in the treatment chamber automatically opens, allowing the entire contents to be released into the Separator, which separates the solid from the liquid components. Once the processed waste is transferred to the Separator additional waste can be loaded and new cycle begun. Three to three and a half cycles per hour can be processed operating at maximum efficiency. The SteriMed is equipped with an integrated monitoring system, including a PLC display, which indicates each of the system's functions to guide the operator through its operations.

### **Types of Waste Treated**

See Section 11.3.10.2. The SteriMed treats conventional healthcare waste, including syringes, needles, blades, dialysis filters, bandages, plastic tubing, and glass.

### **Range of Capacities**

The SteriMed can process up to 70 liters of waste in a 15 minute processing cycle. The SteriMed-Junior can process up to 15 liters of infectious waste, or 3-6 dialysis kits, or 1 sharps container (up to 7.5 liters).

### **Pathogen Destruction**

See Section 11.3.10.4.

### **Emissions and By-Products**

See Section 11.3.10.5.

### **Operation**

There are six stages in the SteriMed-Junior operation: (1) The operator places the untreated waste in the receiver; (2) The loading door is closed and the cycle "start" is initiated; (3) Water and the decontaminating detergent Ster-Cid are introduced into the untreated waste; (4) The next step is the "shred" phase; and (5 & 6) The "discharge and unloading" phases take place, in which the waste is transferred to the solid-liquid Separator or in the case of the SterMed-Junior, the receiver bucket transfers the waste into a filter bag, the material is rinsed and then bag is disposed of as regular waste when full.

### **Installation**

See Section 11.3.10.7. Installation of a SteriMed system requires approximately 90 sq. ft. of floor space, a source of tap water, an electrical outlet, and a drain to the sewerage line. A half-day of training is needed.

### **Maintenance**

See Section 11.3.10.8. Preventive maintenance, both daily and weekly, requires approximately 5-10 minutes.

### **Job Potential**

The Sterimed requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

The SteriMed technology is found in the Azerbaijan, Caribbean, Guam, Serbia, Hungary, United Kingdom, United States, other countries in Europe and elsewhere.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The SteriMed cutting teeth reduce the particle size of the material to approximately 1 to 2.5 cm. The SteriMed Junior reduces the size to approximately 0.5 to 1.5 cm. The SteriMed Junior has wheels.

### **Parameters for Specification**

Capacity, electrical specifications, accessories

### **Photographs**



L-R: SteriMed, Separator, SteriMed-Junior, Ster-Cid chemical disinfectant

**Vendor Information**

M.C.M. Environmental Technologies Ltd. (Kibbutz Moledet, M.P. Gilboa, Israel 19130) was founded in 1993. As of December 2002, M.C.M. Environmental Technologies operated as a subsidiary of Caprius, Inc. and is now headquartered in Paramus, New Jersey, USA.

**Contact Information**

M.C.M. Environmental Technologies, Inc.  
 10 Forest Avenue, Suite 220  
 Paramus, NJ 07652  
 USA  
 Tel.: +1 201.342.1222  
 Fax: +1 201.968.0393  
 Email: sales@mcmtech.com

12.10.3 TRINOVA

**Type of Technology**

Chemical treatment

**Process Description**

Trinova Medical Waste Solutions is a provider of an on-site, healthcare waste treatment system utilizing chlorine dioxide (ClO<sub>2</sub>) as a disinfectant and an internal granulator that pulverizes the waste. The shredded waste is submerged for a short period in an aqueous solution of chlorine dioxide disinfectant and then dewatered. The resulting confetti-like material is then discarded as regular waste. Periodically during the operation of the machine, depleted chlorine dioxide solution is discharged into a neutralization tank where it is then mixed with the neutralization chemicals and monitored for safe disposal into any sanitary sewer.

**Types of Waste Treated**

See Section 11.3.10.2. The technology handles sharps, suction canisters, glass, bandages, swabs, waste contaminated with trace amounts of chemotherapeutic agents, and other types of infectious waste. The Trinova system also destroys confidential medical documents.

**Range of Capacities**

Model	Capacity (kg per hour)
Trinova 2400	270
Trinova 3200	450
Trinova 4200	680

**Pathogen Destruction**

See Section 11.3.10.4. Chlorine dioxide can also treat anthrax-contaminated waste.

**Emissions and By-Products**

See Section 11.3.10.5.

### **Operation**

Waste is shredded into small pieces and falls into a reservoir which is flushed periodically with chlorine dioxide solution into a long reaction coil to provide sufficient contact time. The slurry then flows into a solid-liquid separator or dewatering device. The liquid passes through a fine filter and into the recycling tank. The solids are conveyed into a waste collector or compactor.

### **Installation**

See Section 11.3.10.7. Trinova provides training (in English or Spanish) at customer sites or its facilities in California and Kentucky.

### **Maintenance**

See Section 11.3.10.8.

### **Job Potential**

The Trinova system requires an operator and is automated. Job potential is low.

### **Locations where Technology is in Operation**

The technology is found in the United States.

### **Cost Estimates**

See Section 11.5.3.

### **Special Features**

The Trinova system automatically scans for radioactive waste and weighs the load prior to treatment. All operating parameters are recorded for waste tracking and documentation and to ensure process control.

### **Parameters for Specification**

Capacity, electrical specifications, accessories

### **Photographs**



L-R: Trinova Monarch Green Machine

### **Vendor Information**

Trinova Medical Waste Solutions, LLC was founded in 2003. The first generation technology was installed in 2008 and the Trinova Green Machine was unveiled in 2010. In addition to the technology, the company provides waste stream analysis and evaluation of waste reduction and recycling options.

### **Contact Information**

Trinova Medical Waste Solutions  
235 Jason Court  
Corona, CA 92879  
USA  
Tel.: +1 909-226-0195  
Fax: +1 909-972-1655  
Email: [info@trinovamed.com](mailto:info@trinovamed.com)  
[www.trinovamed.com](http://www.trinovamed.com)

## 12.11 OTHER TECHNOLOGIES

### 12.11.1 CRUSADER ENGINEERING

Crusader Engineering manufactures a hybrid autoclave system for large-scale treatment plants and smaller modular plants. The Crusader technology is a rotating autoclave which is basically a rotating stainless steel drum inside a pressure vessel. Steam is introduced directly into the drum while the rotation breaks open sealed bags and containers. Crusader designs fully automated large-scale plants as well as manually operated modular plants.

Crusader Engineering  
PO Box 204377, Highbrook  
Manukau 2161, Auckland  
New Zealand  
Tel: (+64 9) 274 0811  
Fax: (+64 9) 274 9898  
Email: [info@crusaderengineering.co.nz](mailto:info@crusaderengineering.co.nz)  
<http://www.crusaderengineering.co.nz>

### 12.11.2 GRUPO ATHISA

Grupo Athisa uses a vacuum autoclave with reusable waste containers. They provide 60 liter containers for use in hospitals, health centers, clinics, veterinary clinics, laboratories and pharmacies. The impermeable, hermetically sealed containers have three latches and are color-coded for infectious waste, cytostatic/pharmaceutical waste, and animal remains. The average life span of the containers is one year after which it is recycled. The waste is placed in large carts and placed in the autoclave. The first phase is a vacuum at -0.85 atmospheres. Steam is injected three times. The chamber is heated to 134°C at a pressure of 2.2 atmospheres. Steam is added to maintain the temperature and pressure. In the final phase, steam is released and a vacuum of -0.9 atmospheres is used to dry the waste. Afterwards, the waste is compacted and crushed and discarded as regular waste in a landfill. Grupo Athisa began working in the area of medical waste in 1992. It established its first healthcare waste treatment plant in Lisbon, Portugal in 1996. They have since opened six other plants in Portugal, Spain, and Morocco, treating about 24,000 tons of healthcare waste a year.

Grupo Athisa  
Andaluza Tratamientos de Higiene SA  
Periodista Francisco J. Cobos 18 Portal 1, 1°C  
Granada, Andalucia  
Spain  
Tel: (+34) 958 172 425  
Fax: (+34) 958 170 935  
Email: [kbruck@athisa.es](mailto:kbruck@athisa.es)  
<http://www.athisa.es>

### 12.11.3 LIZHONG MEDICAL WASTE RETORT

Lizhong Food Machinery Co. manufactures medium to large scale medical waste autoclaves. The autoclave is in the form of a retort, a pressurized vessel without an outer jacket. Their medical waste autoclaves have a quick-open door with safety interlock, PLC controls with a touch screen display, and external insulation to conserve energy. The autoclaves are also used for the food, textile, and chemical industries. The company was founded in 1975 to manufacture food processing equipment including steam-digestion mixers, thermal sterilizers, vacuum deep-fryers, vacuum thickener, etc.

Quanzhou City Lizhong Food Machinery Co., Ltd.  
Jiangnan Hi-Tech Industrial Zone, Licheng District  
Quanzhou City, Fujian Province  
China (Mainland) 362000  
Tel.: 86-595-22350867 / 86 13599223028

Fax: 86-595-22469799  
<http://www.food-machinery.com>

#### 12.11.4 ONCORE

Oncore Technology is a chemical treatment system that can treat over 360 kg of waste per hour. It has a processor in which waste is saturated with Onchlor 25, a sodium chlorite based sanitizing agent. Onchlor is automatically generated on demand and enters the sealed chamber as vapor and liquid. An internal opposing blade shredder system macerates the waste to ensure contact with the Onchlor 25 sanitizer. The liquid discharge is treated and the Onchlor 25 is neutralized and pH adjusted before it is discharged to the sanitary sewer. The Oncore processor has a footprint of about 3 x 3 meters.

Oncore Technology  
2613 Skyway Drive  
Grand Prairie, Texas 75052  
USA  
Tel: +1 972 786 706  
Fax: +1 214 988 1808  
<http://www.oncoreus.com>

#### 12.11.5 REGEN VANISH

ReGen LLC's Vanish Technology is a frictional and induction heating type of technology that can process about a ton per hour. A cart lifter dumps the contents into the hopper. The waste then goes into a bag or box opener and into an extruder. Thermal friction extrusion is used to pre-heat and reduce the particle size of the waste. The waste then goes through an induction tube which heats the waste to about 150°C. A PLC controller controls the system. The company is based in the United States with offices in Campinas, SP, Brazil and Dubai, UAE.

ReGen LLC  
50 CR 1672  
Cullman, AL 35058  
USA  
Tel: +1 256-796-7898  
<http://www.vanishwaste.com>

#### 12.11.6 SES SHARPSBLASTER

Safe Environmental Solutions Ltd has a small-scale (4 liter capacity) dry heat technology specifically designed for sharps waste. Special inserts are placed inside puncture-proof disposable metal canisters. Sharps and soft clinical waste are then collected in the containers. When full, the canister is sealed with a lid and transported to the tabletop-size Sharpsblaster. The lid is opened, the canister is placed in the device and the operator pushes the control buttons which causes the lid to lock. The waste is then treated by dry heating to temperatures reaching 165 - 185°C for up to two and a half hours. When cool, the can is removed. Tests have demonstrated a 6 Log<sub>10</sub> reduction of *Geobacillus stearothermophilus* and *Bacillus atrophaeus*. Sharpsblaster offers an optional can compactor to reduce waste volume.

Safe Environmental Solutions Ltd.  
Q Park, Bath Road  
Woodchester, Stroud  
Gloucestershire  
GL5 5HT  
UK  
Tel: +44 (0) 1453 873 809 / 873 810  
Fax: +44 (0) 1453 873 815  
Email: [pr@sharpsblastertm.com](mailto:pr@sharpsblastertm.com)  
[www.sharpsblaster.com](http://www.sharpsblaster.com)

#### 12.11.7 TIANJIN GREENTECH

Tianjin GreenTech offers a steam treatment system and a microwave system. They also provide medical waste shredding equipment and exhaust gas treatment technology. The company specializes in non-incineration technologies for medical waste. They provide installation, commissioning, and maintenance. Tianjin GreenTech has worked for years in cooperation with Tianjin University and Hebei University of Technology.

Tianjin GreenTech Environmental Technology Co., Ltd.  
Tianjin Nankai Science Park  
Tianjin Municipality in North West Tsing District Industrial Park (North Park)  
Star Road on the 26th  
China  
Zip Code: 300380  
Tel.: 022-27985222  
Fax: 022-27985111  
<http://tjgreentech.com/en>

#### 12.11.8 ZEALWAY (XIAMEN) MEDICAL WASTE STERILIZER

Zealway (Xiamen) Instrument Inc. offers small-scale medical waste autoclaves (36, 50, 54, 60 and 80 liter capacities). The sterilizers operate up to 127°C (0.4 mPa pressure) or up to 135°C (0.6 mPa pressure) depending on the model. The autoclaves are controlled by a microcomputer and have 4 or 5 basic treatment programs for solid waste, liquid waste and culture plates. The autoclaves have safety features including interlocks, overpressure and low water level protection.

Zealway (Xiamen) Instrument Inc.  
136-138#, jiu tian hu west 2<sup>nd</sup> road  
Xinglin Industrial Zone, Jimei District  
Xiamen  
China  
Tel: 86-592-779 2033  
Fax: 86-592-261 5099  
Email: [sales@zealway.com.cn](mailto:sales@zealway.com.cn)

## V. TECHNOLOGY ASSESSMENT METHODOLOGY

---

### 13 SUSTAINABILITY ASSESSMENT OF TECHNOLOGIES

---

#### 13.1 OVERVIEW

In response to the need for a technology assessment framework to identify and select the best possible environmental technology option, the International Environmental Technology Centre of the United Nations Environment Program (IETC-UNEP) initiated the development of a systematic procedure whereby a proposed technology intervention is appraised in terms of its potential influence on the environment, the implications for sustainable development, and the likely cultural and socio-economic consequences. Further improvements to the qualitative and comparative life cycle approach in the environmental technology assessment led to a new methodology known as Sustainable Assessment of Technologies (SAT).<sup>199</sup> The focus of this methodology is both on the process as well as outcome, with an interest towards informed and participatory decision making. This component of the Compendium applies the SAT methodology to healthcare waste treatment technologies.

The SAT methodology addresses both strategic and operational levels. Sustainability is a major focus, integrating environmental soundness, social and cultural acceptability, and technical and economic feasibility. The methodology employs a progressive assessment process involving initial screening, scoping and detailed assessment. Importantly, the methodology takes a systems approach and stresses information expertise and stakeholder participation.

Section 13.2 summarizes the SAT methodology and provides suggestions on its use on the strategic level. The operational level assessment is discussed in detail in Section 13.3.

#### 13.2 STEPS OF THE OVERALL SAT METHODOLOGY

The first step in the SAT methodology is to define the problem explicitly. Below are some examples of problems related to healthcare waste management:

- Lack of healthcare waste management has resulted in public health problems in the community as people are exposed to needles and contaminated waste
- Improper healthcare waste management practices pose a risk to the health and safety of health workers, waste collectors and patients in the health facility
- Poor healthcare waste treatment methods have created a serious environmental problem in the local community causing resentment among neighbors affected by foul odors, smoke, air pollutants, contaminated water, or toxic ash from the health facility
- Inadequate waste management practices are putting a strain on the solid waste management system and undermine the potential for material recovery and recycling.

As part of the first step, a situation analysis is undertaken involving collection of baseline data and stakeholder consultations. On a strategic or macro level, baseline data could refer to public health impacts, occupational safety issues (e.g., needle-stick injuries), or environmental impacts related to the lack of healthcare waste management. This information is helpful in defining the problem in concrete terms during stakeholder consultations with local governments, NGOs and the waste generators. The information could also be used in comparative evaluations of scenarios.

During the collection of baseline data, preliminary information could also be obtained on the waste generator(s) and the material characteristics, composition and generation rates of healthcare waste they produced. The information can be obtained using the methods described in Chapter 10, or if this is not possible the information can be estimated using the factors in Chapters 4 to 6 and summarized in Chapter 7.

---

<sup>199</sup> "Application of the SAT Methodology: Guidance Manual," United Nations Environment Programme, 2011.

The next step is the setting of targets for each issue identified during the stakeholder consultations. A “target” specifies how a particular issue can be mitigated. Table 13.2.1 gives a few examples of some possible strategic-level issues and targets that might arise from stakeholder consultations.

Table 13.2.1. Examples of Issues and Targets at the Strategic Level

Healthcare Waste	
ISSUES	TARGETS
All health facilities in the area do not have a way to treat their infectious waste	Implementation of a large-scale central treatment technology to handle infectious waste from all generators in the area; promulgation of policies to require treatment of all infectious waste
Long distances and poor roads between districts preclude one central treatment facility for the province	Designation of a cluster treatment hub in each district and deployment of technology at each hub
Health facilities are remotely located and too far from each other	Implementation of a decentralized treatment scheme with a technology appropriately sized for each facility
The health facility plans to expand the number of beds, types of services, and its area of coverage in the future	Deployment of technology that is modular and can be easily scaled up
Strong public opposition to open burning and air pollution	Deployment of technology with little or no air emissions
Inadequate space in the landfill	Use of technology that results in significant volume reduction and allows materials recovery and recycling; expansion of existing recycling infrastructure
Lack of information and training in healthcare waste management among health workers	Development of training programs and policies requiring training in healthcare waste management as part of facility accreditation and/or professional licensing

At this point, a strategic level assessment is conducted by planners, decision-makers, and elected representatives who brainstorm and examine options at the planning and policy level. This step could entail a technical and economic feasibility study and the use of planning tools such as Logical Framework Analysis<sup>200</sup> or Participatory Project Planning with vision mapping. The information on generic technologies in Chapter 11 can be used for the techno-economic feasibility study.

In situation involving more than one health facility, an important outcome from the stakeholder consultations and strategic level assessment is a decision on whether a decentralized, cluster or centralized treatment approach should be taken (as described in Chapter 9) and which healthcare facilities will be covered under the treatment approach agreed upon.

After the macro-level or strategic level options are finalized, the SAT methodology moves on to an operational level assessment where engineers and other technical personnel conduct a detailed assessment of available technology systems. This step requires expert opinion and more detailed technology information as found in Chapter 12. Details of the operational level assessment in relation to healthcare waste treatment technologies are given in the next section.

The outcome of the operational level assessment is a number of technology system options ranked in the order of their performance relative to the principles of sustainability. However, the selected “best” technology system choice based on current information may later turn out to be inadequate or inappropriate for the future due to changes in the situation, local requirements, legislations, or advances in technology. Hence, before making a final decision, the SAT methodology can be used for a second cycle to simulate possible future scenarios and ensure that the outcome of the first cycle is robust enough to stand the test of time.

The final decision for selecting a particular technology system is then made from the preferred technology options. The next steps involve detailed engineering design, tendering, construction, and commissioning.

<sup>200</sup> More information on Logical Framework Analysis (LFA) or Logframe Approach can be found at <http://www.gdrc.org/ngo/logical-fa.pdf> and [http://www.adb.org/Documents/Guidelines/Logical\\_Framework/default.asp](http://www.adb.org/Documents/Guidelines/Logical_Framework/default.asp)

Continuously monitoring and evaluation of the technology system during its operational phase is an essential next step. This ensures that the technology system is meeting the desired objective vis-à-vis the criteria considered in the SAT methodology. The outcomes of the monitoring and evaluation should be reported to the stakeholder group to inform future decisions at both strategic and operational levels and to serve as input to the situational analysis of a similar future project. This cycle of continuous improvement coupled with public information and consultation distinguishes the SAT methodology.

### 13.3 OPERATIONAL LEVEL ASSESSMENT

As mentioned, after the strategic level options are finalized, the SAT methodology moves on to a more operational level in which technical staff, experts, engineers, etc. assess available technology systems. The following tiered approach is used.

- Tier 1 - Screening: Technology systems are screened against basic criteria which are often in the form of logical operators (i.e. Yes/ No type).
- Tier 2 - Scoping: The technologies that pass through the screening stage are then subjected to a second round of elimination through the scoping tier. Scoping uses select criteria that require more of qualitative or readily available quantitative information. This results in a more limited and more relevant number of technology system options.
- Tier 3 – Detailed Assessment: Technology systems shortlisted from the scoping tier are then subjected to a more rigorous evaluation specially drafted for the purpose, and that demand a greater extent of quantitative information. Additional criteria could be added. This results in a ranking of the top three to five technology systems.

#### 13.3.1 TIER 1 SCREENING

Tier 1 screening is done by a suitable stakeholder group with support from technical and other experts. The criteria considered in Tier 1 screening should ideally be taken from the outcomes of the stakeholder consultation workshops. A list of generic criteria and indicators are presented in Table 13.1 as indicative examples. Developing customized criteria and indicators through consultative meetings and specific to the situation is recommended.

*Table 13.1. Tier 1 Generic Screening Criteria for Healthcare Waste Treatment Technologies*

Heading	Criteria	Indicators	Notes
Compliance	Compliance with local environmental laws	Yes/No	The technology must comply with environmental laws of the city, municipality, district and/or province, such as air pollution or landfill regulations.
Compliance	Compliance with national environmental laws	Yes/No	The technology must comply with national environmental laws, in particular, air pollution, wastewater, and solid waste disposal laws, and healthcare waste or hazardous waste management regulations. Some countries or local governments have banned incineration. Others specify only approved technologies for the treatment of one or more classifications of healthcare waste.
Compliance	Compliance with multilateral environmental agreements	Yes/No	Many countries are parties to the Stockholm Convention on Persistent Organic Pollutants, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Both of these Conventions have guidances related to healthcare waste treatment. The technology should be consistent with these guidances and the country's National Implementation Plans for these treaties.
Other requirements	Consistency with WHO policies	Yes/No	Many countries have adopted the World Health Organization's policy on "Safe health-care waste management" (2004)
Other requirements	Meeting the objectives of 3R programs	Yes/No	Many local governments promote reduce-reuse-recycling programs. The technology should meet the objectives of these local environmental programs.
Other requirements	Other basic criterion	Yes/No	Include other basic criterion from the stakeholder consultation workshops. Examples that might be raised

			during a consultation are: proven technology, good environmental performance, no smoke stack or visible smoke, safe handling of infectious waste, etc.
--	--	--	--

### 13.3.2 TIER 2 SCOPING

The next step also involves stakeholder participation with the support of information experts. Tier 2 scoping criteria may be developed under four categories – technical, financial, social and environmental. As with Tier 1 screening criteria, Tier 2 criteria should be customized for the specific situation and developed through stakeholder consultation. Rather than a simple Yes/No answer, Tier 2 criteria generally require more qualitative or readily available quantitative information.

Depending on the complexity and sensitivity of the decision to be made, as well as the competence and the capability of stakeholder groups, a range of quantification and aggregation techniques can be applied in the scoping process. The simplest is a weighted sum matrix (or decision matrix) that is used here. Essentially, a weight (weighting factor) is assigned to each criterion within a category based on the importance given to it by the stakeholders undertaking the assessment. The number or score assigned to the technology reflects how well the technology complies with each defined criterion as judged by the stakeholders. The scores are multiplied by their corresponding weights and added up within each category to arrive at a total score for that category.

Tables 13.2 to 13.5 are lists of generic scoping criteria which can be used as a guide. Tier 2 scoping criteria should be customized for specific situations.

Table 13.2. Tier 2 Generic Scoping Criteria for Healthcare Waste Treatment Technologies:  
*Technical Suitability*

Criteria	Indicators	Notes
Compatibility with local surroundings and natural conditions	Low/ Medium/ High	Is the proposed technology system suitable for the geographical or climatic condition? Is it suitable for the topography? For example, technologies that release pollutants through a chimney may not be appropriate in valleys where atmospheric inversions are frequent. If the area is in a seismic zone or flood plain, how will earthquakes or floods impact the technology? If the technology will be installed next to residences, the impact of dust, smoke, noise and odors should be considered.
Preference for locally manufactured technologies	Low/ Medium/ High	In countries where treatment technologies are locally made, preference could be given to local manufacturers to reduce costs and support local employment.
Availability of spare parts and usage of local materials	Low/ Medium/ High	To minimize downtime, consumable items and spare parts should be readily available. If there are no locally manufactured technologies, preference could be given to technologies that make use of locally made accessories, consumable items, and spare parts.
Availability of local expertise	Low/ Medium/ High	It would be essential to have the necessary local expertise for commissioning as well as operation, maintenance and repair of the technology. If local expertise is not available, preference could be given to vendors that are willing to train local operators and technicians to run and maintain the technology.
Track record on performance	Low/ Medium/ High/ Not available	Before making a decision about any technology system option, it is essential to check the track record of the technology as well as the vendor.
Compatibility with existing technology or management system	Low/ Medium/ High	In some cases, it is possible that the new technology system would build upon some existing system. As such, it is essential that the new system is compatible with the existing infrastructure/ technology systems as well as the organization's management systems.
Ideal capacity	Low/ Medium/ High	The specific model or unit of the technology should match closely with the expected capacity or estimated range of capacities required.
Adaptability to future situations	Low/ Medium/ High	In order to get the maximum benefit from the technology intervention, it is essential to check the flexibility or adaptability of the technology system for the future scenarios. This may, for instance, include the scale-up / expansion possibility or technology upgrade for improving efficiency in order to meet the changing needs, such as plans to increase hospital beds or open outpatient clinics. It may be useful to

		undertake some scenario building exercises to decide on this aspect.
Ability to treat a wide range of healthcare wastes	Low/ Medium/ High	Except in cases where the facility generates a specific category of waste or a limited number of waste categories, the desired technology should be able to treat a wide range of healthcare wastes.
Level of automation / sophistication	Low/ Medium/ High	The levels of automation and sophistication relate to the ease of operation and reduce the risk of operator error. Automation also means less manual handling of waste and could mean a lower risk of exposure to pathogens.

Table 13.3. Tier 2 Generic Scoping Criteria for Healthcare Waste Treatment Technologies: Environment (Resources and Emissions)

Criteria	Indicators	Notes
Efficacy of microbial inactivation	Low/ Medium/ High	It is essential that the technology can be shown to achieve the minimum level of disinfection required to ensure that pathogens have been destroyed.
Risk levels for workers	Low/ Medium/ High	It is essential to assess the potential environmental, health and safety risks to the workers. It may be necessary to conduct a full-fledged risk assessment exercise in some instances, while in other cases this decision can simply be made by a review of the literature and expert opinions. It is important to note that higher scores should be assigned for lower risks when assigning the scores for the ratings during weighted sum matrix.
Risk levels for communities/ beneficiaries	Low/ Medium/ High	It is essential to assess the potential environmental, health and safety risks to the communities/ beneficiaries. It may be necessary to conduct a full-fledged risk assessment exercise in some instances, while in other cases this decision can simply be made by a review of the literature and expert opinions. It is important to note that higher scores should be assigned for lower risks when assigning the scores for the ratings during weighted sum matrix.
Risk to the environment e.g. to biodiversity	Low/ Medium/ High	It is essential to assess the potential environmental, health and safety risks to the environment/ biodiversity. It may be necessary to conduct a full-fledged risk assessment exercise in some instances, while in other cases this decision can simply be made by a review of the literature and expert opinions. It is important to note that higher scores should be assigned for lower risks when assigning the scores for the ratings during weighted sum matrix.
Air emissions	Low/Medium/ High	Some technologies, such as steam-based systems, have minimal air emissions while others, such as incinerators, release significant air contaminants that require air pollution abatement. The emission levels from the air pollution control system and the efficiency and reliability of the control devices themselves should be evaluated. Higher scores should be assigned for lower air emissions when assigning the scores for the ratings during weighted sum matrix.
Liquid effluents	Low/Medium/ High	Liquid effluents—such as sterile condensate, wastewater with high biological oxygen demand, spent chemical disinfectants, or contaminated effluents from scrubbers—are released in varying amounts and impact the environment differently. Higher scores should be assigned for lower environmental impacts when assigning the scores for the ratings during weighted sum matrix.
Solid residues	Low/Medium/ High	Some residues, such as sterilized plastics, have lower health/safety and environmental risks, compared to other residues, such as unshredded needles or incinerator ash. Higher scores should be assigned for lower environmental impacts when assigning the scores for the ratings during weighted sum matrix.
Volume reduction	Low/Medium/ High	Higher reduction in volume could mean lower transportation and disposal costs and lower impact on landfill space.
Mass reduction	Low/Medium/ High	Higher reduction in mass could mean lower transportation and disposal costs.
Odor	Low/ Medium/ High	The issue of odors is significant to the workers. It is also a concern when there are residences or commercial facilities adjacent to the technology site. Higher scores should be assigned for lower odor when assigning the scores for the ratings during weighted sum matrix.
Noise	Low/ Medium/ High	Hammer mills and some shredders may generate unacceptable levels of noise especially if the treatment plant is adjacent to the community. Higher scores should be assigned for lower noise levels when

		assigning the scores for the ratings during weighted sum matrix.
Energy consumption per kg of waste	Low/ Medium/ High	Energy sources could be in the form of electricity, diesel and other fuel oils, kerosene, natural gas, liquefied petroleum gas (LPG), coal, local fuels, etc. Higher scores should be assigned for lower energy consumption while assigning the scores for the ratings during weighted sum matrix.
Extent of use of renewable energy	Low/ Medium/ High	Some technologies may be able to take advantage of renewable energy, such as solar water heaters for autoclave steam generators.
Water consumption per kg of waste	Low/ Medium/ High	Water could be used in the treatment process itself (such as steam-based technologies or chemical treatment) or in air pollution control devices (such as wet scrubbers). Higher scores should be assigned for lower water consumption while assigning the scores for the ratings during weighted sum matrix.
Material consumption	Low/ Medium/ High	Some technologies require single-use containers (e.g., burn boxes, encapsulating canisters, etc.) for use with their systems. Except for technologies designed for reusable containers, most technologies require disposable plastic bags. Chemical treatment and some air pollution control systems consume chemical compounds. Some technologies use compressed air for pneumatic systems to operate doors, valves or controls. With high temperature systems like incinerators, the refractory in the combustion chambers may need periodic replacement. Higher scores should be assigned for lower material consumption while assigning the scores for the ratings during weighted sum matrix.
Extent of use of hazardous materials	Low/ Medium/ High	Chemical treatment technologies use compounds that are generally hazardous (e.g., hypochlorite, chlorine dioxide, alkali, etc.). This is a safety and occupational health issue for the workers as well as a potential safety issue for nearby communities in the event of a large-scale chemical spill or accidental release. Higher scores should be assigned for lower hazardous material use while assigning the scores for the ratings during weighted sum matrix.
Space requirement	Low/ Medium/ High	Some technologies are more compact than others. This criterion could be important in facilities with limited space. Higher scores should be assigned for lower space requirement while assigning the scores for the ratings during weighted sum matrix.
Resource recovery capabilities	Low /Medium/ High	Resource recovery is a potential side benefit and should be considered. For example, steam-based technologies allow the possibility of recovery and recycling of shredded materials (sterile plastics, glass, metal, etc.). Excess heat from incinerators could be used to recover energy for hot water or space heating. Alkaline digestion technologies leave behind calcium residues that could be recovered and used as soil conditioners. For this decision, one can rely on expert opinions and past case studies as well as vendor information.

Table 13.4. Tier 2 Generic Scoping Criteria for Healthcare Waste Treatment Technologies:  
Economic / Financial Aspects

Criteria	Indicators	Notes
Capital cost of the treatment technology	Low/ Medium/ High	As much as possible, the capital costs should include shipment, customs, installation, start-up, testing, and commissioning costs. Various aspects related to costs can be assessed primarily by referring to vendor information, technology fact sheets and sometimes expert opinions. Higher scores should be assigned for lower costs when assigning the scores for the ratings during weighted sum matrix.
Capital costs of all accessories and related equipment	Low/ Medium/ High	The capital costs of all necessary accessories and related equipment should also be considered. These accessories could include containers, bins, trolleys, weighing scales, conveyors, bin loaders and other waste handling equipment, transport vehicles, boilers, computer controls, shredders, compactors, skips or dumpsters, water treatment systems, air pollution control systems, wastewater treatment systems, etc. Various aspects related to costs can be assessed primarily by referring to vendor information, technology fact sheets and sometimes expert opinions. Higher scores should be assigned for lower costs when assigning the scores for the ratings during weighted sum matrix.
Operation and maintenance costs	Low/ Medium/ High	The main operating costs are labor, fuel (diesel, gas, etc.), electricity, water, consumables (personal protection equipment, disposable boxes and bags, labels, cleaning supplies, etc.), sewage, and landfill

		disposal costs, as well as preventive maintenance and repair costs including replacement parts. A system costing approach would also include additional costs such as administration, periodic training, regulatory fees, and employee benefits. Various aspects related to costs can be assessed primarily by referring to vendor information, technology fact sheets and expert opinions. Higher scores should be assigned for lower costs when assigning the scores for the ratings during weighted sum matrix.
Installation requirements	Low/ Medium/ High	If installation costs are not included in the capital cost of the technology, they should be estimated based on vendor information, technology fact sheets and expert opinions. Installation includes site preparation, foundation, construction or renovation of the space where the treatment technology will be located (including electrical service, steam or water lines, lighting, drainage, ventilation, etc.), chimney and duct work, and construction of temporary waste storage areas. Higher scores should be assigned for lower installation requirements when assigning the scores for the ratings during weighted sum matrix.

Table 13.5. Tier 2 Generic Scoping Criteria for Healthcare Waste Treatment Technologies: Social / Cultural Aspects

Criteria	Indicators	Notes
Community acceptance of the technology	Low/ Medium/ High	Some technologies are easier to understand than others. For example, where pressure cookers and microwave ovens are common, communities are able to accept autoclave and microwave technologies more readily. Hospital personnel are generally already familiar with autoclaves and incinerators. However, many communities may be opposed to the siting of incinerators in their neighborhoods. This criterion can be evaluated through stakeholder consultation workshops and by using information from surveys.
Income generation potential	Low/ Medium/ High	Job potential may be an important consideration in the community. The job potential can be assessed primarily by referring to vendor information, technology fact sheets and expert opinions.
Acceptability of treatment residues	Low/ Medium/ High	The acceptability of residues may depend on religious or cultural norms. Some communities may require that all healthcare waste be rendered unrecognizable. Others may require the burial of body parts and may not accept the burning, sterilizing or chemical decomposition of anatomical waste.
Extent of necessary resettlement of people	Low/ Medium/ High	Technology systems that use a lot of space or that should be sited far away from populations may mean the relocation of people. These may be other important social equity issues related to this criterion. Higher scores should be assigned for lower extent of resettlement required when assigning the scores for the ratings during weighted sum matrix.
Visible or aesthetic impact	Low/ Medium/ High	Many communities are opposed to the sight of flue gas stacks and visible smoke. Higher scores should be assigned for lower negative visual impacts when assigning the scores for the ratings during weighted sum matrix.

### 13.3.3 TIER 3 DETAILED ASSESSMENT

The technologies that scored the highest or above a cut-off score in the Tier 2 analysis are carried over to Tier 3. The Tier 3 assessment demands a lot more detailed and quantitative information. Details about the technologies obtained from the vendor, price quotations, data from Chapter 12, and other available information are carefully analyzed. Based on this additional evaluation, the top ranked technologies are subjected once more to an analysis but this time a multi-criteria star diagram can be used. Star diagrams condense and organize data about multiple attributes, which are the chosen categories (technical, financial, social and environmental) in the case of the SAT methodology. In some instances, the rating of the technology systems may change due to more careful scrutiny or new available information. The outcome of this process is a ranking of the top three or five technologies.

#### 13.3.4 REVIEW AND JUSTIFICATION

A review of the options may reveal that an option that does not qualify as a high-end scorer may merit being among the top choices if appropriate technology transfer, adaptation or capacity building efforts are undertaken. This is an important consideration before discarding the low-scoring options. Hence a broader examination of the options, going beyond the numbers, is highly recommended.

After one cycle of the SAT method has been completed, it is recommended that possible future scenarios be considered to ensure that the outcome of the exercise is robust enough to stand the test of time. It may also be necessary that the cycle has to be repeated if new information is obtained or if there are significant changes to the local situation, technical or financial requirements, legislation, or technological developments. These may change the criteria, weights and scores and may ultimately alter the technology choices.

In the end, a written justification of the top technology choices helps clarify the selection, ensures that there is agreement among decision-makers, and is a useful feedback to share with the participating stakeholders.

#### 13.4 RECOMMENDED STEPS USING THE SAT METHODOLOGY

The steps outlined in this section are intended as a general guide. They should be modified and customized to meet local situations.

##### 13.4.1 **STEP 1. DEFINE THE SCOPE OF THE PROBLEM, OBTAIN BASELINE DATA, AND CONDUCT STAKEHOLDER CONSULTATIONS**

Define the problem. Obtain baseline data, specifically, concrete information that supports the problem statement and information on each of the healthcare facilities concerned (e.g., number of beds, average occupancy rates, number of outpatients per day, anticipated percent growth in healthcare services in the next 10-15 years, and current healthcare waste management practices) as well as data on the healthcare waste produced by the healthcare facilities.

Identify stakeholders, such as local governments, waste generators (e.g., hospitals, clinics, doctors' offices, etc.), non-governmental organizations (e.g., organizations of medical professionals, hospital associations, health worker and waste worker unions, environmental groups, public health and infection control societies, etc.), civil society organizations (e.g., neighborhood organizations, citizens' groups, schools), private sector representatives (landfill operators, equipment vendors, waste hauling companies), and other appropriate stakeholders.

Organize consultations with the stakeholders. During the stakeholder consultation workshops, summarize key points from the baseline data, validate or modify the problem definition, identify and prioritize issues of concern, and obtain initial input on possible solutions.

#### **EXAMPLE 1**

The neighborhood organization around Hospital A complained to the local government that dense smoke from the district hospital's old incinerator was causing problems in the community. They presented the results of a study by a public health research group which indicated a higher rate of respiratory disorders including asthma among households downwind of the incinerator compared to the general population. The study was reported in the local newspaper and caused a public outcry.

The district obtained basic data to evaluate the issue. They took photos of the incinerator emissions during operation. Since there was no capability to do an opacity test, the district's environment health office used a Ringelmann chart to determine that the smoke density was between 4 and 5 in the Ringelmann scale. The district also evaluated the public health study and conducted a survey which showed that the majority of residents living in the district were opposed to the old incinerator.

The district identified the following stakeholders: the neighborhood organization, families living downwind of the incinerator, hospital administration, chief medical and nursing officer of the hospital, hospital hygiene/infection control

officer of the hospital, hospital engineer, hospital waste workers, the public health researchers, the district environmental health office that documented the problem, local media, state environmental regulator, and various district officials. Representatives of each group were invited to attend a public stakeholder workshop.

During the workshop, the district showed photos of the incinerator emission, explained the Ringelmann scale and high smoke density, summarized the results of their survey, and invited the public health researchers to present their study. The neighborhood organizational representative reiterated their demand that the old incinerator be closed down. The state regulator reported that the state environmental council had plans to impose a moratorium on open burning and any new incineration construction in the province beginning in six months due to high air pollution levels in the state. Everyone including the hospital administration agreed that the incinerator was a problem.

The hospital director explained that they reduced the amount of waste burned by arranging to dispose of small amounts of anatomical waste (body parts from surgery) through interment at a special area in the local cemetery as allowed by law. However, the hospital had to continue using the incinerator to treat infectious waste generated every day. They had been negotiating with the nearest central treatment facility but it was 500 km away passing through roadways that were not paved in sections. Responding to the community's concerns, the hospital agreed to work with the local government and stakeholders to find an on-site solution.

The consensus at the workshop was that environmental issues, in particular air emissions and compliance with state environmental regulations, were the highest priority, followed by social issues (community acceptance, no visible negative impact). Finally, technical and economic issues were seen as important especially by the hospital.

## ***EXAMPLE 2***

After a television reporter showed poor children playing with needles and fresh blood bags at an open dumpsite, an NGO working with waste pickers and a local environmental group requested the mayor of the city to investigate.

City officials verified the presence of untreated waste in the open dumpsite and closed the dumpsite in favor of the local municipal landfill. The city decided to review healthcare waste management practices at all its health facilities. The city health officer found that out of the five hospitals in the city, four were not in compliance with national medical waste laws, in particular, with the treatment and disposal requirements. The large tertiary hospital with 600 beds used an old incinerator which was often not used due to the cost of diesel fuel and the lack of spare parts. One hospital discarded infectious waste with its regular waste and two hospitals used old brick burners with no pollution control. One private hospital was in compliance due to its own modern on-site treatment system. The city also discovered that 30 clinics were non-compliant as well. Four other clinics had arrangements with the private hospital to treat their infectious waste.

The city government announced a stakeholders' workshop and invited the following: the three hospitals and 20 clinics that were in violation of the regulations; the NGO working with poor children and waste pickers; the local environmental advocacy group; the local medical association and nursing society; syndicate of waste workers; private waste collection service provider; municipal landfill operator; local plastic, glass and paper recyclers; and various city government officials.

During the workshop, the city health officer presented her findings and played a video of the TV report to illustrate the problem posed by non-compliance with the national medical waste laws. Many of the health facilities stated that they had been searching for on-site treatment options but the technologies were either unavailable or too expensive.

After much discussion, all the health facilities agreed in principle to a cost-sharing agreement with the city if the city government invested in a centralized treatment system to be installed at a city property next to the municipal landfill. The waste collection provider agreed to invest in a vehicle to collect waste daily from all the health facilities and transport the waste to the treatment plant. The landfill operator agreed in principle to accept the treated waste. The environment group offered to train waste pickers and provide them with personal protection equipment if the city enforced occupational safety laws, if the landfill operator supervised the recycling operation, and if the recyclers and landfill operators provided fair compensation to the waste pickers.

The stakeholders agreed that compliance with existing laws and environmental compliance, technical issues (especially the ability to meet capacity requirements), economic sustainability, and social acceptance were of equal priority.

13.4.2 **STEP 2. CONDUCT A STRATEGIC LEVEL ASSESSMENT AND DETERMINE THE DESIRED WASTE TREATMENT APPROACH**

Compile the input from the stakeholder consultation workshops. Organize stakeholder group meetings with planners, decision-makers, and elected representatives to conduct a strategic level assessment. Obtain consensus on the treatment approach—decentralized on-site treatment, cluster treatment or centralized treatment—and on the healthcare facilities to be covered under the treatment approach (see Chapter 8). If agreement on the treatment approach has not been reached, gather and present additional data (Step 3) to facilitate informed choices by the stakeholders and repeat Step 2.

**EXAMPLE 1**

The local government convened a meeting of the hospital administrator, hospital engineer, district planner, environmental health officer, local and state environmental regulators, a technical expert hired by the district, and members of the district commission. The hospital engineer presented some waste data that showed that the 150-bed hospital generated 120 kg of infectious waste per day and 80 kg of regular waste per day. The environmental health officer noted that this corresponded to a generation rate of 0.8 kg of infectious waste per bed per day, which was much higher than the national average. The hospital agreed to hire a healthcare waste management consultant and implement a segregation program in order to determine the actual amounts of infectious waste generated.

**EXAMPLE 2**

The mayor convened a meeting of the administrators of the four hospitals and 30 clinics; a scientist with the environmental group; the head of waste workers syndicate; the president of the private waste collection service provider; municipal landfill operator; a plastic/glass recycler; the city health officer and city planner; and members of the city council. Each stakeholder agreed to sign a letter of intent agreeing in principal to a cost-sharing arrangement. The health facilities agreed to work with a consultant hired by the city to obtain waste generation data.

13.4.3 **STEP 3. VERIFY FACILITY-SPECIFIC DATA OR OBTAIN ADDITIONAL FACILITY-SPECIFIC DATA THROUGH A WASTE ASSESSMENT OR COMPARISON WITH ESTIMATION FACTORS**

Verify facility-specific data or obtain additional data from the specific facilities to be included in the treatment system agreed upon in Step 2. At this point, the most important information needed for technology selection relates to the material characteristics, composition, waste generation rates of healthcare waste produced by the healthcare facilities of concern, and required processing capacities. Use the calculation methods described in Chapters 8 and 10, and for data gaps, use the estimating factors in Chapters 4 to 6 and summarized in Chapter 7.

**EXAMPLE 1**

During the second meeting of the stakeholder group, the hospital engineer presented revised waste data based on a segregation system implemented with the help of a healthcare waste consultant. With good segregation, the 150-bed hospital actually generated only 45 kg of infectious waste per day and 155 kg per day was regular waste. This corresponded to a generation rate of 0.3 kg of infectious waste per bed per day, which was consistent with waste generation rates for hospitals practicing segregation. The hospital engineer also reported an average density for infectious waste of 100 kg/m<sup>3</sup> which was a reasonable figure. The hospital administrator stated that they expected to increase the number of beds by 10% in the next 10 years. The district planner confirmed that his office estimated a population growth rate for the district of about the same figure.

Based on the revised data, the expert suggested that an on-site treatment system would be appropriate. The hospital wanted to treat their infectious waste within one eight-hour shift. The expert estimated that a treatment system with a

throughput rate of about 7.5 kg per hour or a capacity of 75 liters per hour would allow the hospital to treat their infectious waste in six hours. Even with a 10% expansion in 10 years, the hospital would only have to extend the operating time to less than seven hours even with more than an hour extra for start-up, daily checks and maintenance, and shut-down.

**EXAMPLE 2**

At the next meeting, the consultant reported that he had worked with all the health facilities in improving their segregation practices and estimated the following infectious waste generation rates: 570 kg of total infectious waste per day from all facilities; the three hospitals each with 300 beds and the tertiary hospital with 600 beds produced an average of 0.35 kg per bed per day; and the 30 clinics average 150 patients per day and generate about 0.01 kg per patient per day. Bulk densities were about 120 kg/m<sup>3</sup>. All the figures were found to be similar to averages in other countries. A technology at a central treatment plant serving all these health facilities would require a throughput of 570 kg/day or a volumetric capacity of 4750 liters per day. The plant could operate for eight hours, which the stakeholders agreed with. The city planner suggested allowing for a 20% increase in the next 10-15 years due to the expected expansion of the city. This meant that the throughput rate could be 95 kg/hr or 790 liter/hr for a 6 to 8 hour operation.

**13.4.4 STEP 4. CONDUCT A TIER 1 SCREENING PROCESS TO ELIMINATE GENERIC TECHNOLOGIES THAT DO NOT MEET THE BASIC CRITERIA**

From the stakeholder consultation workshops, determine basic criteria and devise a simple worksheet to eliminate generic technologies that do not meet the basic criteria. Organize an appropriate stakeholder group. Present information on generic technologies (see Section 11.3) and use the worksheet to conduct the Tier 1 screening. The generic technology categories that have not been eliminated are then carried over to the next step. Table 13.6 gives an example of a Tier 1 screening worksheet.

*Table 13.6. Sample Tier 1 Screening Worksheet*

Criteria	Autoclave	Hybrid autoclave	Continuous steam	Batch microwave	Continuous microwave	Frictional heating	Dry heating	Incinerator	Alkaline hydrolysis	Chemical treatment
Compliance with local environmental laws	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Compliance with national environmental laws	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Compliance with multilateral environmental agreements	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Consistency with WHO policies	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Eliminate?										

**EXAMPLE 1**

After determining the throughput rate, the group reviewed the comments from the first stakeholders' workshop and conducted a Tier 1 screening. The expert gave a description of each of the technology categories. The environmental regulators mentioned that there were no environmental guidelines for alkaline hydrolysis and chemical treatment. Alkaline hydrolysis was eliminated since it was primarily for anatomical waste which was already taken care of through burial. Incineration was also eliminated due to past non-compliance and in order to conform with the planned moratorium on incineration in the province. The resulting Tier 1 worksheet is shown below.

Criteria	Autoclave	Hybrid autoclave	Continuous steam	Batch microwave	Continuous microwave	Frictional heating	Dry heating	Incinerator	Alkaline hydrolysis	Chemical treatment
Compliance with local environmental laws	Y	Y	Y	Y	Y	Y	Y	N	?	?
Compliance with national environmental laws	Y	Y	Y	Y	Y	Y	Y	N	?	?
Compliance with multilateral environmental agreements	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Consistency with WHO policies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eliminate?	Y	Y	Y	Y	Y	Y	Y	N	N	N

**EXAMPLE 2**

This consultant described each of the technology categories in relation to compliance with existing environmental laws. The group agreed that all the technologies met the basic criteria. The resulting Tier 1 worksheet is shown below.

Criteria	Autoclave	Hybrid autoclave	Continuous steam	Batch microwave	Continuous microwave	Frictional heating	Dry heating	Incinerator	Alkaline hydrolysis	Chemical treatment
Compliance with local environmental laws	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Compliance with national environmental laws	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Compliance with multilateral environmental agreements	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Consistency with WHO policies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eliminate?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

**13.4.5 STEP 5. CONDUCT A TIER 2 SCOPING PROCESS TO GENERATE A SHORTER LIST OF POTENTIAL TECHNOLOGIES**

The next step is to decide on preferred aspects or criteria of the desired technology. The criteria should be based on the stakeholder consultation workshops and the strategic level assessments. Some of the criteria may require input from technical specialists. Unlike Step 4, a Tier 2 scoping process introduces a weighting factor to reflect differences in the priority or significance of each criterion. A decision has to be made as to the relative importance of each criterion (as reflected in an appropriate weighting factor) and the cut-off score below which technologies will be eliminated.

Firstly, the stakeholders are requested to rank the relative importance of each of the four topics (technical suitability, environment, economic/financial, and social/cultural). In the worksheet in Table 13.7, the rankings of the four topics (RT, REN, REc and RS in the shaded column) should add up to 100.

*Table 13.7. Sample Worksheet for Relative Ranking of the Four Topics*

Establish the relative importance of the sets of criteria topics below by assigning a factor from 0 to 100 to each topic such that the sum of all the ranking factors adds up to 100. For example, assign 25 to each topic if they are all of equal importance.

Criteria Topic	Ranking (0 to 100)	
Technical suitability	RT =	
Environment (resources and emissions)	REn =	
Economic/financial aspects	REc =	
Social/cultural aspects	RS =	
	TOTAL	100

Then the stakeholders are asked to establish weighting factors (0 to 10) for each of the criteria. Information from Chapters 11 and 12 can be used in this evaluation. A set of draft weighting factors could also be done by a consultant, planner or a subset of stakeholders specifically interested in each topic. Ideally, the weighting factors are discussed with the stakeholders and modified as needed before the technology scoring is done.

Table 13.8 gives an example of a worksheet and instructions to establish the weighting factors. The weighting factors are designated as W1 to W37 and placed in the shaded column.

Table 13.8. Sample Worksheet for Establishing Weighting Factors

Weight each criteria from 0 to 10 (0 for not important, 1 to 3 for low, 4 to 6 for medium, 7 to 9 for high, and 10 for essential). Refer to the Notes in Tables 13.2 to 13.5 for guidance.

Criteria	Weight
Technical Suitability	
Compatibility with local surroundings and natural conditions	W1 =
Preference for locally manufactured technologies	W2 =
Availability of spare parts and usage of local materials	W3 =
Availability of local expertise	W4 =
Track record on performance	W5 =
Compatibility with existing technology or management system	W6 =
Meets capacity requirement	W7 =
Adaptability to future situations	W8 =
Ability to treat a wide range of healthcare wastes	W9 =
Level of automation / sophistication	W10 =
Environment	
Efficacy of microbial inactivation	W11 =
Risk levels for workers	W12 =
Risk levels for communities	W13 =
Risk to the environment	W14 =
Air emissions	W15 =
Liquid effluents	W16 =
Solid residues	W17 =
Volume reduction	W18 =
Mass reduction	W19 =
Odor	W20 =
Noise	W21 =
Energy consumption per kg of waste	W22 =
Extent of use of renewable energy	W23 =
Water consumption per kg of waste	W24 =
Material consumption	W25 =
Extent of use of hazardous materials	W26 =

Space requirement	W27 =	
Resource recovery capabilities	W28 =	
Economic/Financial		
Estimated capital cost of the treatment technology	W29 =	
Estimated capital costs of all accessories and related equipment	W30 =	
Estimated operation and maintenance costs	W31 =	
Installation requirements	W32 =	
Social/Cultural		
Community acceptance of the technology	W33 =	
Income generation potential	W34 =	
Acceptability of treatment residues by the local landfill	W35 =	
Extent of necessary resettlement of people	W36 =	
Visible or aesthetic impact	W37 =	

Before conducting the actual Tier 2 scoping process, multiplying factors have to be calculated for each criterion. First calculate maximum scores for each topic as follows:

Maximum score for Technical Suitability (MST):  
 $MST = 9 \times (W1+W2+W3+W4+W5+W6+W7+W8+W9+W10)$

Maximum score for Environment (MSEn):  
 $MSEn = 9 \times (W11+W12+W13+W14+W15+W16+W17+W18+W19+W20+W21+W22+W23+W24+W25+W26+W27+W28)$

Maximum score for Economic/Financial (MSEc):  
 $MSEc = 9 \times (W29+W30+W31+W32)$

Maximum score for Social/Cultural (MSS):  
 $MSS = 9 \times (W33+W34+W35+W36+W37)$

Now calculate the multiplying factors as follows:

- MF1 = W1 x RT/MST
- MF2 = W2 x RT/MST
- MF3 = W3 x RT/MST
- MF4 = W4 x RT/MST
- MF5 = W5 x RT/MST
- MF6 = W6 x RT/MST
- MF7 = W7 x RT/MST
- MF8 = W8 x RT/MST
- MF9 = W9 x RT/MST
- MF10 = W10 x RT/MST
- MF11 = W11 x REn/MSEn
- MF12 = W12 x REn/MSEn
- MF13 = W13 x REn/MSEn
- MF14 = W14 x REn/MSEn
- MF15 = W15 x REn/MSEn
- MF16 = W16 x REn/MSEn
- MF17 = W17 x REn/MSEn
- MF18 = W18 x REn/MSEn
- MF19 = W19 x REn/MSEn
- MF20 = W20 x REn/MSEn
- MF21 = W21 x REn/MSEn
- MF22 = W22 x REn/MSEn
- MF23 = W23 x REn/MSEn
- MF24 = W24 x REn/MSEn
- MF25 = W25 x REn/MSEn
- MF26 = W26 x REn/MSEn
- MF27 = W27 x REn/MSEn
- MF28 = W28 x REn/MSEn
- MF29 = W29 x REc/MSEc
- MF30 = W30 x REc/MSEc
- MF31 = W31 x REc/MSEc

MF32	=	W32	x	REc/MSEc
MF33	=	W33	x	RS/MSS
MF34	=	W34	x	RS/MSS
MF35	=	W35	x	RS/MSS
MF36	=	W36	x	RS/MSS
MF37	=	W37	x	RS/MSS

These multiplying factors should now be incorporated in the Tier 2 Scoping Worksheet which will be used for scoring each technology. A sample Tier 2 Scoping Worksheet is shown in Table 13.9.

Table 13.8. Sample Tier 2 Scoping Worksheet

For each technology under consideration, score each criteria from 0 to 9 (1 to 3 for low, 4 to 6 for medium, 7 to 9 for high) according to the Notes in Tables 13.2 to 13.5. Multiply each score by its corresponding multiplying factor (MF). Add the weighted scores (scores x MF) for each technology. Eliminate technologies that score below the cut-off point.

Criteria	MF	Technology 1		Technology 2		Technology 3		Etc.
		Score	Score x MF	Score	Score x MF	Score	Score x MF	
TOPIC 1: TECHNICAL SUITABILITY								
Compatibility with local surroundings and natural conditions	MF1							
Preference for locally manufactured technologies	MF2							
Availability of spare parts and usage of local materials	MF3							
Availability of local expertise	MF4							
Track record on performance	MF5							
Compatibility with existing technology or management system	MF6							
Meets capacity requirement	MF7							
Adaptability to future situations	MF8							
Ability to treat a wide range of healthcare wastes	MF9							
Level of automation / sophistication	MF10							
TOPIC 2: ENVIRONMENT								
Efficacy of microbial inactivation	MF11							
Risk levels for workers	MF12							
Risk levels for communities	MF13							
Risk to the environment	MF14							
Air emissions	MF15							
Liquid effluents	MF16							
Solid residues	MF17							
Volume reduction	MF18							
Mass reduction	MF19							
Odor	MF20							

Noise	MF21							
Energy consumption per kg of waste	MF22							
Extent of use of renewable energy	MF23							
Water consumption per kg of waste	MF24							
Material consumption	MF25							
Extent of use of hazardous materials	MF26							
Space requirement	MF27							
Resource recovery capabilities	MF28							
TOPIC 3: ECONOMIC/FINANCIAL								
Estimated capital cost of the treatment technology	MF29							
Estimated capital costs of all accessories and related equipment	MF30							
Estimated operation and maintenance costs	MF31							
Installation requirements	MF32							
TOPIC 4: SOCIAL/CULTURAL								
Community acceptance of the technology	MF33							
Income generation potential	MF34							
Acceptability of treatment residues by the local landfill	MF35							
Extent of necessary resettlement of people	MF36							
Visible or aesthetic impact	MF37							
		Total =		Total =		Total =		

### EXAMPLE 1

Another meeting was called by the district and it involved the hospital administrator, hospital engineer, representatives of the medical and nursing staff, the union representative of the waste workers, a representative of the neighborhood association and a local engineer living in the community, one of the public health researchers, the district planner, environment health officer, and two members of the district commission. During the stakeholders meeting, the technical expert provided information when requested by the participants. The following relative rankings of topics were agreed upon: RT=15, REn=40, REc=15, and RS=15. The technical expert presented a set of draft weighting factors for each criterion. After minor modifications, the weighting factors shown below were accepted.

Criteria	Weight	
<b>Technical Suitability</b>		
Compatibility with local surroundings and natural conditions	W1 =	1
Preference for locally manufactured technologies	W2 =	5
Availability of spare parts and usage of local materials	W3 =	3
Availability of local expertise	W4 =	1
Track record on performance	W5 =	10
Compatibility with existing technology or management system	W6 =	1
Meets capacity requirement	W7 =	10
Adaptability to future situations	W8 =	5
Ability to treat a wide range of healthcare wastes	W9 =	10
Level of automation / sophistication	W10 =	10
<b>Environment</b>		
Efficacy of microbial inactivation	W11 =	10
Risk levels for workers	W12 =	10
Risk levels for communities	W13 =	10
Risk to the environment	W14 =	10
Air emissions	W15 =	10
Liquid effluents	W16 =	5
Solid residues	W17 =	1
Volume reduction	W18 =	10
Mass reduction	W19 =	3
Odor	W20 =	10
Noise	W21 =	5
Energy consumption per kg of waste	W22 =	10
Extent of use of renewable energy	W23 =	5
Water consumption per kg of waste	W24 =	5
Material consumption	W25 =	5
Extent of use of hazardous materials	W26 =	5
Space requirement	W27 =	3
Resource recovery capabilities	W28 =	3
<b>Economic/Financial</b>		
Estimated capital cost of the treatment technology	W29 =	10
Estimated capital costs of all accessories and related equipment	W30 =	5
Estimated operation and maintenance costs	W31 =	10
Installation requirements	W32 =	5
<b>Social/Cultural</b>		
Community acceptance of the technology	W33 =	10
Income generation potential	W34 =	5
Acceptability of treatment residues by the local landfill	W35 =	10
Extent of necessary resettlement of people	W36 =	5
Visible or aesthetic impact	W37 =	5

These weighting factors were used to compute the multiplying factors which were then incorporated into the Tier 2 Scoping Worksheet. The expert then presented ten technologies that were available and met the basic criteria from Tier 1, the minimum throughput rates and other requirements determined in the previous meeting. The worksheet below shows the results only for the top three technologies.

Criteria	MF	Technology 1		Technology 2		Technology 3	
		Score	Score x MF	Score	Score x MF	Score	Score x MF
<b>TOPIC 1: TECHNICAL SUITABILITY</b>							
Compatibility with local surroundings and natural conditions	0.030	8	0.24	7	0.21	5	0.15
Preference for locally manufactured technologies	0.149	9	1.34	6	0.89	6	0.89
Availability of spare parts and usage of local materials	0.089	7	0.63	8	0.71	4	0.36
Availability of local expertise	0.030	9	0.27	5	0.15	7	0.21
Track record on performance	0.298	8	2.38	6	1.79	6	1.79
Compatibility with existing technology or management system	0.030	9	0.27	7	0.21	5	0.15
Meets capacity requirement	0.298	8	2.38	8	2.38	6	1.79
Adaptability to future situations	0.149	8	1.19	6	0.89	5	0.74
Ability to treat a wide range of healthcare wastes	0.298	9	2.68	7	2.08	6	1.79
Level of automation / sophistication	0.298	7	2.08	8	2.38	6	1.79
<b>TOPIC 2: ENVIRONMENT</b>							
Efficacy of microbial inactivation	0.370	9	3.33	8	2.96	7	2.59
Risk levels for workers	0.370	8	2.96	6	2.22	5	1.85
Risk levels for communities	0.370	7	2.59	5	1.85	6	2.22
Risk to the environment	0.370	8	2.96	7	2.59	5	1.85
Air emissions	0.370	8	2.96	6	2.22	4	1.48
Liquid effluents	0.185	9	1.67	8	1.48	6	1.11
Solid residues	0.037	9	0.33	7	0.26	5	0.19
Volume reduction	0.370	8	2.96	9	3.33	7	2.59
Mass reduction	0.111	7	0.78	6	0.67	6	0.67
Odor	0.370	9	3.33	5	1.85	5	1.85
Noise	0.185	8	1.48	7	1.30	3	0.56
Energy consumption per kg of waste	0.370	8	2.96	6	2.22	6	2.22
Extent of use of renewable energy	0.185	9	1.67	7	1.30	7	1.30
Water consumption per kg of waste	0.185	8	1.48	5	0.93	9	1.67
Material consumption	0.185	7	1.30	8	1.48	5	0.93
Extent of use of hazardous materials	0.185	7	1.30	6	1.11	7	1.30
Space requirement	0.111	8	0.89	7	0.78	9	1.00
Resource recovery capabilities	0.111	9	1.00	8	0.89	6	0.67
<b>TOPIC 3: ECONOMIC/FINANCIAL</b>							
Estimated capital cost of the treatment technology	0.556	8	4.44	8	4.44	5	2.78
Estimated capital costs of all accessories and related equipment	0.278	9	2.50	6	1.67	6	1.67
Estimated operation and maintenance costs	0.556	7	3.89	9	5.00	8	4.44
Installation requirements	0.278	8	2.22	6	1.67	5	1.39

TOPIC 4: SOCIAL/CULTURAL							
Community acceptance of the technology	0.952	8	4.44	8	4.44	5	2.78
Income generation potential	0.476	9	2.50	6	1.67	6	1.67
Acceptability of treatment residues by the local landfill	0.952	7	3.89	9	5.00	8	4.44
Extent of necessary resettlement of people	0.476	8	2.22	6	1.67	5	1.39
Visible or aesthetic impact	0.476	8	4.44	8	4.44	5	2.78
		Total = 89.1		Total = 78.7		Total = 65.5	

**EXAMPLE 2**

The stakeholders agreed on equal relative rankings of topics: RT=25, REN=25, REc=25 and RS=25. The group then divided into four subgroups and determined initial weighting factors. All the stakeholders then came together, discussed the draft weighting factors, revised several of them, and agreed on the weighting factors shown below.

Criteria	Weight	
Technical Suitability		
Compatibility with local surroundings and natural conditions	W1 =	1
Preference for locally manufactured technologies	W2 =	7
Availability of spare parts and usage of local materials	W3 =	6
Availability of local expertise	W4 =	6
Track record on performance	W5 =	10
Compatibility with existing technology or management system	W6 =	3
Meets capacity requirement	W7 =	10
Adaptability to future situations	W8 =	7
Ability to treat a wide range of healthcare wastes	W9 =	10
Level of automation / sophistication	W10 =	10
Environment		
Efficacy of microbial inactivation	W11 =	10
Risk levels for workers	W12 =	10
Risk levels for communities	W13 =	10
Risk to the environment	W14 =	10
Air emissions	W15 =	10
Liquid effluents	W16 =	5
Solid residues	W17 =	5
Volume reduction	W18 =	10
Mass reduction	W19 =	3
Odor	W20 =	10
Noise	W21 =	5
Energy consumption per kg of waste	W22 =	10
Extent of use of renewable energy	W23 =	8
Water consumption per kg of waste	W24 =	5
Material consumption	W25 =	5
Extent of use of hazardous materials	W26 =	5
Space requirement	W27 =	3
Resource recovery capabilities	W28 =	5
Economic/Financial		
Estimated capital cost of the treatment technology	W29 =	10
Estimated capital costs of all accessories and related equipment	W30 =	5
Estimated operation and maintenance costs	W31 =	10
Installation requirements	W32 =	5
Social/Cultural		
Community acceptance of the technology	W33 =	10
Income generation potential	W34 =	5
Acceptability of treatment residues by the local landfill	W35 =	10
Extent of necessary resettlement of people	W36 =	5
Visible or aesthetic impact	W37 =	7

These were then used to compute the multiplying factors used in the Tier 2 Scoping Worksheet. The group again divided into four subgroups. Each subgroup was tasked to score three technologies. The whole group discussed the findings of each subgroup and agreed on the scores for the 12 available technologies. The worksheet below shows the results only for the top three technologies.

Criteria	MF	Technology 1		Technology 2		Technology 3	
		Score	Score x MF	Score	Score x MF	Score	Score x MF
<b>TOPIC 1: TECHNICAL SUITABILITY</b>							
Compatibility with local surroundings and natural conditions	0.040	8	0.32	7	0.28	8	0.32
Preference for locally manufactured technologies	0.278	9	2.50	8	2.22	6	1.67
Availability of spare parts and usage of local materials	0.238	8	1.90	8	1.90	8	1.90
Availability of local expertise	0.238	9	2.14	7	1.67	7	1.67
Track record on performance	0.397	8	3.17	9	3.57	6	2.38
Compatibility with existing technology or management system	0.119	9	1.07	7	0.83	5	0.60
Meets capacity requirement	0.397	8	3.17	9	3.57	8	3.17
Adaptability to future situations	0.278	9	2.50	6	1.67	5	1.39
Ability to treat a wide range of healthcare wastes	0.397	9	3.57	7	2.78	7	2.78
Level of automation / sophistication	0.397	7	2.78	8	3.17	6	2.38
<b>TOPIC 2: ENVIRONMENT</b>							
Efficacy of microbial inactivation	0.215	9	1.94	8	1.72	7	1.51
Risk levels for workers	0.215	8	1.72	7	1.51	5	1.08
Risk levels for communities	0.215	9	1.94	8	1.72	8	1.72
Risk to the environment	0.215	8	1.72	7	1.51	5	1.08
Air emissions	0.215	8	1.72	7	1.51	7	1.51
Liquid effluents	0.108	9	0.97	8	0.86	6	0.65
Solid residues	0.108	9	0.97	7	0.75	8	0.86
Volume reduction	0.215	8	1.72	9	1.94	7	1.51
Mass reduction	0.065	8	0.52	8	0.52	6	0.39
Odor	0.215	9	1.94	9	1.94	8	1.72
Noise	0.108	8	0.86	7	0.75	3	0.32
Energy consumption per kg of waste	0.215	9	1.94	6	1.29	6	1.29
Extent of use of renewable energy	0.172	9	1.55	7	1.21	8	1.38
Water consumption per kg of waste	0.108	9	0.97	9	0.97	9	0.97
Material consumption	0.108	7	0.75	8	0.86	7	0.75
Extent of use of hazardous materials	0.108	8	0.86	6	0.65	7	0.75
Space requirement	0.065	9	0.58	7	0.45	9	0.58
Resource recovery capabilities	0.108	9	0.97	8	0.86	7	0.75
<b>TOPIC 3: ECONOMIC/FINANCIAL</b>							
Estimated capital cost of the treatment technology	0.926	8	7.41	8	7.41	8	7.41
Estimated capital costs of all accessories and related equipment	0.463	9	4.17	7	3.24	6	2.78
Estimated operation and maintenance costs	0.926	9	8.33	9	8.33	8	7.41
Installation requirements	0.463	8	3.70	8	3.70	7	3.24

TOPIC 4: SOCIAL/CULTURAL							
Community acceptance of the technology	0.751	8	6.01	8	6.01	5	3.75
Income generation potential	0.375	9	3.38	9	3.38	8	3.00
Acceptability of treatment residues by the local landfill	0.751	9	6.76	9	6.76	8	6.01
Extent of necessary resettlement of people	0.375	9	3.38	7	2.63	5	1.88
Visible or aesthetic impact	0.526	9	4.73	7	3.68	7	3.68
		Total =	94.6	Total =	87.8	Total =	76.2

13.4.6 **STEP 6. CONDUCT A TIER 3 DETAILED ASSESSMENT TO COME UP WITH A RANKING OF THE TOP TECHNOLOGIES**

Step 6 focuses on the five or so technologies that scored the highest or on all the technologies that scored above a cut-off score in Step 5. The shorter list of technologies is subjected to a more rigorous review by the stakeholders. Or perhaps another weighted sum matrix or a revision of the previous assessment may be done using new information obtained from the vendor, additional data, or input from technical consultants to come up with a more refined ranking of the top three or five technologies.

After the Tier 3 Detailed Assessment has validated or further refined the analysis from the previous step, the data can then be plotted in a star diagram (also called radar chart, polar plot or kiviati diagram) to make it easier to visualize the scores.

The Tier 3 Detailed Assessment approach can be part of a competitive bidding process commonly undertaken for procurement of products and services by public agencies. It begins with the preparation and issuance of an Invitation to Bid (also called a call for bids, call for tenders, invitation to tender, invitation of tenders, or request for proposal). The invitation to bid document generally includes the project background, the response required from the bidder, the procedure and timetable for the selection of the winning bid, and specific requirements related to the technology or service desired. Usually, the list of criteria on which bidders will be evaluated and the corresponding weighting factors are included.

The Invitation to Bid is published in official journals and websites, advertised through newspapers and public notices, or sent to a list of pre-qualified vendors. A two-envelope system is often used: the bidder must submit the technical proposal (or statement of work) and the cost proposal in two separate sealed envelopes. The objective is to ensure a fair evaluation such that the technical proposal is evaluated purely on its technical merits and its ability to meet the specified requirements without being unduly biased by the financial proposal. The Invitation to Bid specifies a strict deadline for submission and a physical location or address where the bids must be submitted. Each bid received is given a reference number.

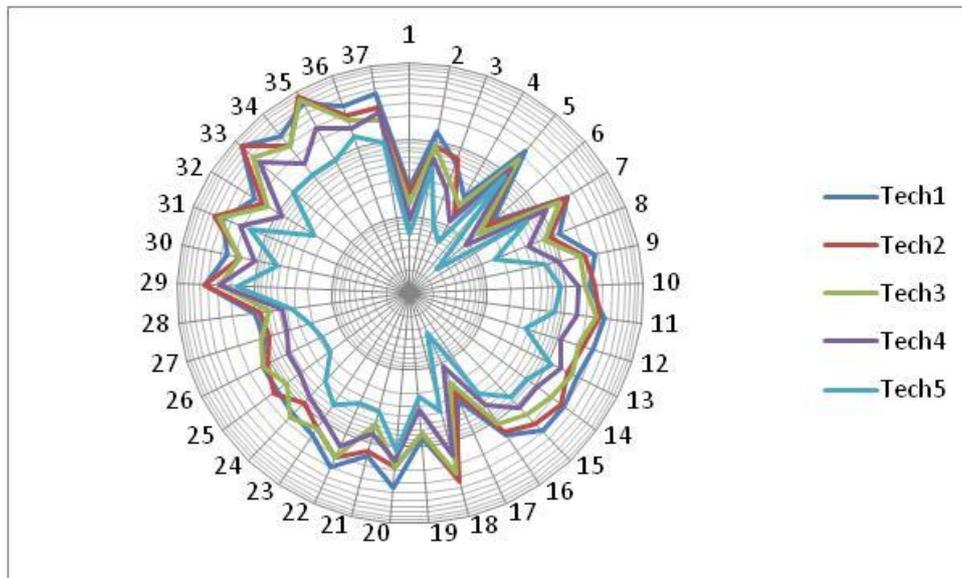
After the deadline, the sealed envelopes are opened by representatives of the procurement (contracting) authority in the presence of witnesses. Depending on the legal requirements, a minimum of three or five bids is required. The legal process of selection usually has three phases. The first is an assessment of the qualifications of the bidders in relation to legal and financial requirements, such as having legal status, having no previous criminal convictions for fraud or corruption, and financial capacity and stability. This phase is skipped if the bidder has already been evaluated and pre-qualified under these requirements.

The next phase is a review of the technical proposal and a scoring of the bidders by a technical review committee. This is equivalent to a Tier 3 Detailed Assessment *excluding* an evaluation of costs. Low-scoring bids or bids that score below a cut-off point are eliminated.

The third phase is a review of the cost proposals of the remaining bids, often conducted by a separate review committee. The lowest-price bidder is awarded the contract. Alternatively, the contract is awarded to the bidder that meets the contract award criteria established in the Invitation to Bid; the award criteria could combine price and other factors involving technical merit and quality.

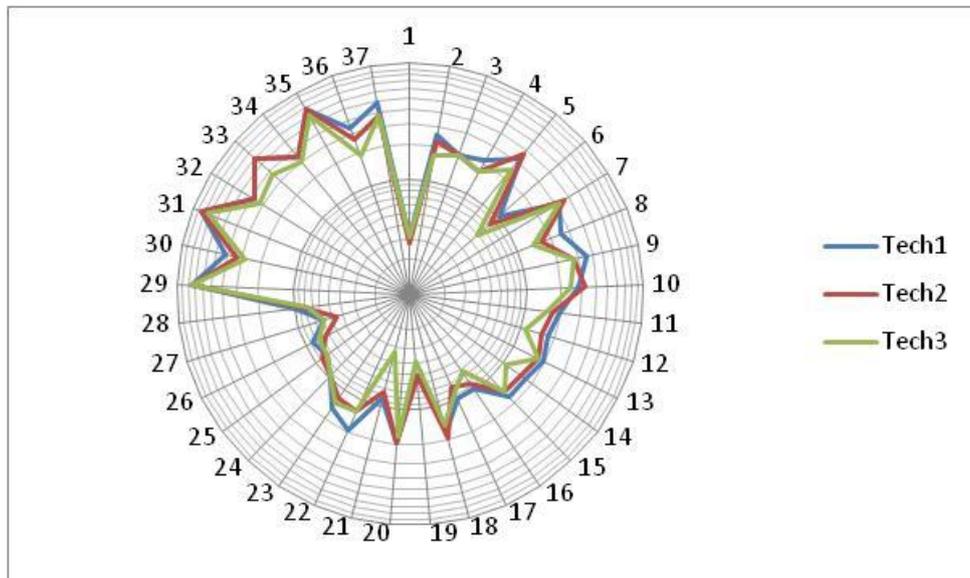
**EXAMPLE 1**

The technical expert working with the district planner took the final scores and presented them in the form of a star diagram or radar chart of the top five technologies. In order to distinguish the technologies, a logarithmic scale was used for the radar axis. The chart showed that Technology 1 (dark blue line) was the top candidate although Technology 2 (red line) and Technology 3 (green) were strong contenders.



**EXAMPLE 2**

The consultant plotted the final scores of the top three technologies and presented them to the stakeholders. A logarithmic radar scale was used. All three technologies were fairly close although Technology 1 (blue) was the best candidate.



13.4.7 **STEP 7. REVIEW THE RESULTS AND PREPARE A WRITTEN JUSTIFICATION FOR THE SELECTION OF THE TOP TECHNOLOGIES**

Before discarding the low-scoring options, review the options for the possibility that appropriate technology transfer, adaptation or capacity building efforts may qualify some of the low-scoring technologies to be added to the top ranks. Explore possible future scenarios and check for changes in the local situation, technical or financial requirements, legislation, or technological developments. Repeat Steps 5 and 6 if deemed necessary due to these changes. This step is omitted in a competitive bidding process.

Write a justification of the top technology choices and ensure that there is agreement among decision-makers. Provide copies of the justification to participating stakeholders.

13.4.8 **STEP 8. AWARD THE CONTRACT.**

The contract is generally awarded to the lowest-price bidder or the bidder that best meets the contract award criteria. Sometimes contractual issues arise, such as problems with regards to price, availability, delivery schedule or customization. If so, an agreement is negotiated between the bidder and contracting authority. If a negotiated agreement is not reached or if the bidder is found to be unable to meet the requirements, a contract is awarded to the next lowest-price bidder or the next bidder that meets the contract award criteria, or the bidding process is reopened and the procedure is repeated.

13.4.9 **STEP 9. IMPLEMENT THE INSTALLATION AND COMMISSIONING OF THE TECHNOLOGY.**

If the bidder fulfills the contract with the shipment, installation, start-up, testing, commissioning and operator training, the contracting authority completes payment as stated in the contract terms. Sometimes the final payment tranche is made after a regulatory body certifies the technology.

13.4.10 **STEP 10. MONITOR AND EVALUATE THE PERFORMANCE OF THE TECHNOLOGY.**

It is recommended to monitor and evaluate the technology system during its operational phase to ensure that it is meeting the desired objective and criteria considered in the SAT methodology. The outcomes of the

monitoring and evaluation should be reported to the stakeholders, including government agencies, planners and other decision-makers that took part in the selection. This feedback can be helpful for future decision-making at both strategic and operational levels.

---

NOTE: UNEP has developed an interactive Excel-based software that facilitates the Sustainable Assessment of Technologies methodology for selecting healthcare waste treatment technologies. The software and manual are available from:

International Environmental Technology Centre  
Division of Technology, Industry & Economics  
United Nations Environment Programme  
2-11- Ryokuchi koen, Tsurumi-ku  
Osaka 538-0036 Japan

## About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: **climate change, harmful substances and hazardous waste, resource efficiency.**

DTIE is also actively contributing to the **Green Economy Initiative** launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

***The Office of the Director, located in Paris, coordinates activities through:***

- > **The International Environmental Technology Centre** - IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- > **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- > **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- > **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- > **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- > **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

***DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.***

For more information,  
[www.unep.org/dtie](http://www.unep.org/dtie)

**www.unep.org**

United Nations Environment Programme  
P.O. Box 30552 Nairobi, Kenya  
Tel.: ++254-(0)20-762 1234  
Fax: ++254-(0)20-762 3927  
E-mail: [unep@unep.org](mailto:unep@unep.org)



UNEP DTIE  
International Environmental  
Technology Centre (IETC)

2-110 Ryokuchi Koen, Tsurumi-ku  
Osaka 538-0036, Japan  
Tel: +81 6 6915 4581  
Fax: +81 6 6915 0304

E-mail: [ietc@unep.org](mailto:ietc@unep.org)  
URL IETC: <http://www.unep.org/ietc/>

DTI/1561/JA