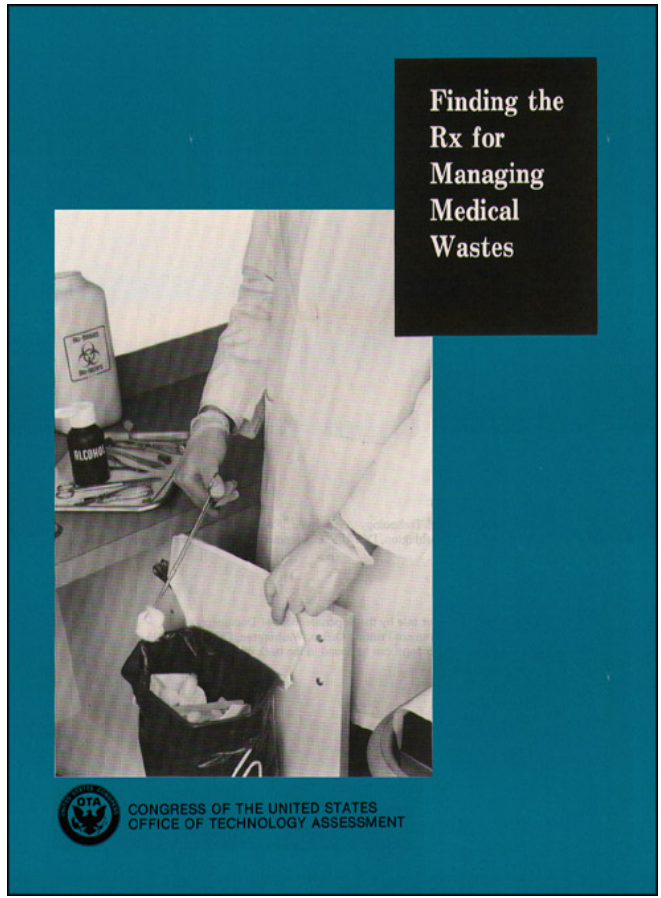
Finding the Rx for Managing Medical Wastes

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Foreword

The adequate management of medical wastes first became a major focus of public attention when medical wastes with other debris washed ashore on the East Coast in the summer of 1988. In October of that year, as part of OTA's assessment of municipal solid waste management, OTA issued a background paper entitled Issues in Medical Waste Management. That study provided an overview of medical waste disposal practices and potential risks associated with them, and discussed the need for further Federal involvement in managing medical wastes.

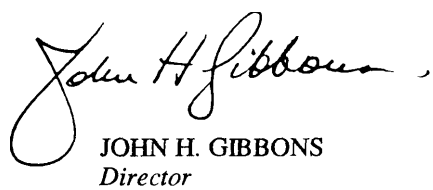
Also in October of 1988, Congress passed the Medical Waste Tracking Act, establishing a 2-year demonstration tracking program for medical waste management and directing the Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry to complete several studies to evaluate management issues and potential risks related to medical waste disposal.

Some studies by these and other government agencies, and by private-sector interests, have been completed since that time on various aspects of medical waste management issues. The focus of concern has shifted primarily to the adequacy of handling, treatment, and disposal practices for medical wastes. Public concern remains high and much of the confusion and inconsistency associated with medical waste policy persists.

This OTA report was requested by the House Committee on Science, Space, and Technology, the House Subcommittee on Transportation and Hazardous Materials, Committee on Energy and Commerce, and the House Subcommittee on Regulation, Business Opportunities and Energy, Committee on Small Business. The report evaluates medical waste issues in the broader context of a waste management policy for the Nation. Waste reduction and recycling options for medical waste management, as well as incineration and non-incineration treatment alternatives are examined.

Applying a more comprehensive waste management approach to medical wastes, such as has evolved for municipal solid waste and hazardous waste, could help ensure environmentally sound and economically feasible waste practices. At a minimum, we realize that (as with most waste problems) there is no one management scenario to "solve" our medical waste problems; rather the most important task is to devise policies that will facilitate adoption of individually optimal solutions to specific problems.

OTA benefited from the assistance received from many organizations and individuals during the course of this study. We express our gratitude and thanks to the review panel and the many other reviewers for their input which greatly facilitated the preparation of the report. OTA, however, is solely responsible for the contents of this report.



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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the workshop participants, advisory panel members, and reviewers. These participants do not, however, necessarily approve, disapprove, or endorse this special report. OTA assumes full responsibility for the special report and the accuracy of its contents.

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Introduction, Major Findings, and Policy Issues

Two years after the beach washups of medical wastes in a hot summer,[1] preliminary results from investigations by Federal agencies into medical waste management issues are being reported.[2] At the same time, many State and local governments (107, 139,110) and several private groups (77) have undertaken efforts to better address the management of medical wastes. Certainly, more is known about current medical waste management practices than prior to the passage of the Medical Waste Tracking Act (MWTA) in October 1988[3] (see app. A). Yet, much of the confusion and inconsistency associated with medical waste policy persist. Basic information as well as consensus on some fundamental management issues remain absent from the efforts to formulate a adequate national medical waste policy.

As current governmental studies and efforts are completed, it is clear that critical aspects of medical waste issues need to be addressed further:

- Consensus on the definition of regulated medical wastes must develop, based on the potential health risks posed by these wastes (e.g., the ability of a particular type of medical waste to pose a risk of infectious disease transmission beyond that associated with municipal solid waste).
- Basic, more precise information on the generation (amounts and disposal methods) of medical wastes, particularly by non hospital sources, is needed.
- Potential waste reduction and recycling opportunities to improve medical waste management need to be investigated, including consideration of product redesign to produce reusable and recyclable medical products where appropriate, or to avoid use of problematic (e.g., cadmium and lead) components in products.
- Appropriate workplace practices for occupational groups in frequent contact with medical wastes (e.g., health-care workers, refuse workers) need to be developed by relevant governmental agencies and adopted by employers to minimize the occupational hazards posed by these wastes.
- Information on treatment technologies, inparticular nonincineration alternatives, needs to be more readily available to State and local regulators, to generators, and to the general public.
- Air emission standards for medical waste incinerators, expected to be completed in a couple of years by the Environmental Protection Agency (EPA), are needed to create a more certain regulatory climate. Procedures to establish the safety and efficacy of new treatment technologies are needed.
- Management options for small generators of medical waste (including households) must be developed and information on their availability should be more readily available.

Before a comprehensive approach to medical waste management can be pursued, gaps in information and research that limit resolution of these issues must be better addressed. Some of the necessary studies, particularly those that better characterize the nature of health risks posed by medical wastes, will require significant commitments of time and funding, e.g., for epidemiologic and longitudinal studies.

The Office of Technology Assessment (OTA), in a background paper released in October 1988, Issues in Medical Waste Management, briefly examined the adequacy of current medical waste disposal practices, the potential risks from such practices, and the need for further Federal requirements for the handling, treatment, storage, and disposal of medical wastes. The focus of this OTA report is: 1) to place medical waste problems in a broader waste reduction and materials management perspective, as is evolving for municipal solid waste (MSW) and hazardous waste; and 2) to address a number of outstanding issues on incineration and other medical waste treatment technologies.

[1] The causes and impacts of the beach washups of medical waste are discussed in a separate effort (11s).

[2] Namely, the studies of medical waste issues mandated by the Medical Waste Tracking Act to be completed by the Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry, as discussed below.

[3] The Medical Waste Tracking Act is amended as new Subtitle J to the Solid Waste Disposal Act and the Resource Conservation and Recovery Act (Public Law 89-272; 42 U.S.C. 6901 et seq.).

Medical wastes are defined to include all the types of wastes produced by hospitals, clinics, doctors' offices, and other medical and research facilities.[4] These wastes include infectious, hazardous[5] radioactive, and other general wastes from these health-care and medical facilities. Infectious wastes are a relatively small portion of medical wastes, although a high level of concern regarding their management exists.[6] For purposes of this report, regulated medical wastes are those infectious, potentially infectious, and special wastes designated by EPA as such under MWTA (see app. A). Throughout this report, the regulated medical waste stream is the primary focus and is usually referred to as such unless another type of medical waste (e.g., low-level radioactive, hazardous, etc.) is being discussed.

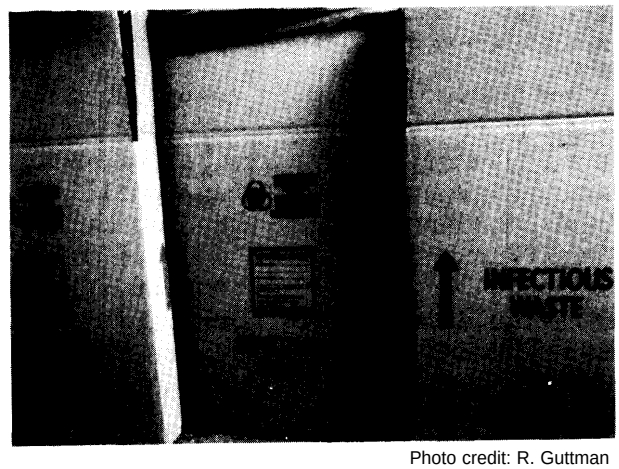


Photo credit: R. Guttman

Infectious wastes, although a relatively small portion of all types of medical wastes, are the principal focus of regulatory concern.

All medical wastes represent a small portion of MSW. Estimates for medical waste, exclusive of that generated from home health-care (for which reliable national estimates do not exist), range from 0.3 to 2 percent of the total municipal solid waste stream (130, 114).[7] The amount of infectious waste generated by medical facilities as a percentage of their total waste stream varies widely depending on the type of health-care facility, the definition of infectious waste used, and the standard operating procedures specified by it for designating and separating waste types. Most hospitals, however, designate about 15 percent of their waste as infectious (95).

EPA reports that autoclaving (i.e., steam sterilization) is utilized nationally to treat most infectious medical waste (141, 49, 139). However, medical waste incinerators continue to be a source of public concern, particularly because there are no national emission control standards for them (because their small size exempts them from current standards). EPA is in the process of developing new source performance standards (NSPS) for medical waste incinerators, which are expected to be proposed in 1992 (41; see ch. 4). Meanwhile, many States have developed new regulations to control these sources (107). To date, even less regulatory development has occurred for autoclaves or other nonincineration treatment alternatives (see ch. 3).

Nearly 70 percent of the Nation's hospitals use on-site incinerators. There is, however, great variation in the type, nature, and use of these incinerators. Some are used only for pathological waste disposal; others are used for disposal of infectious and noninfectious medical wastes.

Only a few States have reliable information on the number, types, and conditions of treatment units operating in their States. The State of Washington, for example, in its recent survey of medical waste practices, found that somewhere between 48 and 87 percent of the incinerators operating in the State were doing so without emission control equipment (139). The State of California reports that most of its 146 operating medical waste incinerators are small, uncontrolled units; 94 percent are on-site units (107). Recently, data has been reported that indicates that the rates of toxic emissions from medical waste incinerators (without emission controls) exceed those from modern MSW incinerators (106). Interestingly, the State of California also reports that a maximum of 60 percent of the waste burned in these

[4]Medical wastes from households are generally considered to be part of the municipal solid waste stream. As noted throughout this report, however, certain items such as syringes, which can be generated in significant quantities by households, may warrant separate and special management practices. Further, wastes similar to those identified as medical wastes may be generated by such facilities as police crime investigation units, mortuaries, veterinary clinics, etc.

[5]It should be noted that in this context "hazardous" is a legal designation, not necessarily a measure of the actual hazard of a particular waste.

[6]It is important to emphasize that not all medical waste is infectious. As EPA noted in its guidance document, defining infectious waste as waste capable of producing an infectious disease requires consideration of factors necessary for induction of disease. These factors include: presence of a pathogen of sufficient virulence, dose, portal of entry, and resistance of the host (122).

[7]EPA estimates that 2 to 3 million tons of infectious *hospital* waste is generated annually.

incinerators is regulated medical waste, the remaining 40 percent being municipal waste (107).

EPA, the Centers for Disease Control (CDC), the Occupational Safety and Health Administration (OSHA), and other Federal agencies have issued different, general guidelines for infectious and medical waste management (see table 1). Differences of opinion exist over the importance and impact of variations between the definitions and recommendations of these government agencies. Any remaining confusion over government positions on these matters could be eliminated if Congress designated a lead agency to coordinate and clarify the Federal Government positions on medical waste issues. As noted in OTA's previous background paper on medical waste, EPA is the agency with the most comprehensive authority to provide Federal leadership on the management of medical wastes (114).

OTA's statement in that background paper still applies: "Currently, no Federal regulations exist that comprehensively address the handling, transportation, treatment, and disposal of medical waste" (emphasis added; 114). This means that variation exists among the requirements that States and localities have devised for medical waste management. In recent years, such variations have led observers to suggest that the Federal Government needs to establish some baseline, uniform standards and guidelines for medical waste management. To date, the Federal Government has been reluctant to act without greater information on a number of issues related to medical waste management (114).

Some of this information may come from studies that both the EPA and the Agency for Toxic Substances and Disease Registry (ATSDR) are required to conduct under MWTA (sees. 11008 and 11009). MWTA (sec. l1008(a)) requires EPA to evaluate and include in reports to Congress: generator information (types, number, and size); on-site and off-site management practices, including sewer use; types and amounts of medical wastes; costs associated with the improper management of medical waste and those from compliance with the regulatory requirements of MWTA demonstration program; available and potential reduction, reuse, and management methods; implications of regulatory exemptions of household and small quantity generators; guidelines for the management of medical waste from households and small-quantity generators; existing State and local controls; and the appropriateness of applying Subtitle C requirements

Table l—Major Federal Agencies Addressing Medical Waste Issues

Agency	Authority	Activity
U.S. Environmental Protection Agency (EPA)	Guidance and Regulatory [a]	Issued Guide for Infectious Waste Management; issued regulations to establish the Medical Waste Tracking Program; establishing new source performance standards for medical waste incinerators; completing studies requested by the Medical Waste Tracking Act; authority under the Resource Conservation and Recovery Act to regulate the handling, storage, and transportation of medical wastes.
Occupational Safety and Health Administration, U.S. Department of Labor (OSHA)	Guidance and Regulatory [b]	Issues advisory notices and workplace standards focusing on occupational exposure to infectious materials and wastes.
Centers for Disease Control, U.S. Department of Health and Human Services (CDC)	Guidance and Recommendations [c]	Issues notices and advisories, sometimes jointly with OSHA, focusing on infection and control issues.
Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services (ATSDR)	Study and Reviev [c]	Completing study required by the Medical Waste Tracking Act, focusing on evaluating health effects associated with medical wastes.

[a] EPA's comprehensive authority to regulate medical waste management is granted under the Resource Conservation and Recovery Act. The Agency also has special regulatory authority to administer a demonstration medical waste tracking program and is required to complete a number of studies related to medical waste management under the Medical Waste Tracking Act (42 U.S.C. 6901 et seq.).
[b] OSHA's primary authority is granted under the Occupational Safety and Health Act (29 U.S.C. 651 et seq.). Guidelines or regulations only apply to private facilities, unless a State extends coverage to employees of public facilities as well.
[c] Does not have the authority to issue regulations.

SOURCE: Office of Technology Assessment, 1990.

(i.e., the hazardous waste provisions) of the Resource Conservation and Recovery Act (RCRA) to medical wastes.

EPA has concentrated its implementation efforts thus far on promulgating and implementing the requirements for the MWTA demonstration program. The regulations were promulgated ahead of schedule in March 1989 and became effective in June 1989 (Federal Register, Mar. 22, 1989). The Agency and its contractor convened a meeting in November 1988 with health-care and waste industry, environmental, and various State and Federal Government representatives to discuss ways to collect information on medical waste generation and management practices as part of this effort (123). EPA's first of three required reports to Congress under the law, highlighting the efforts to address the issues under study, was delayed by more than a year. This delay was due, at least in part, to inaction by the Office of Management and Budget (OMB) in its review of the report. The first report is expected to review what EPA plans to study and focus on the proposed approach for a health hazard assessment (89).

ATSDR is required to report on such health effects of medical waste as: estimates of the number of people annually infected or injured by medical wastes (including sharps), including descriptions of the nature and seriousness of those incidents; and estimates of the number of cases traceable to medical waste of diseases that could be spread by improper management of such wastes (in particular, hepatitis B virus (HBV), and immunodeficiency virus (HIV), or AIDS). Its report to Congress on the public health implications of medical waste is expected to be released on schedule on November 1, 1990.[8]

The EPA and ATSDR studies are limited because existing information and data are inadequate (134). Still needed are research, surveys and studies that generate new information and address existing data gaps.

To address these research needs is beyond the scope of this report, which is intended to provide a framework for considering medical waste management issues and to assess in a preliminary way the potential of various reduction and treatment methods for medical waste.[9] The report is divided into six chapters: 1) applying a comprehensive waste management strategy to medical waste and a brief review of Federal efforts undertaken to date; 2) exploring pretreatment approaches (e.g., waste reductions and recycling options); 3) exploring nonincineration medical waste treatment technologies and emerging treatment technologies; 4) examining current issues regarding incineration of medical wastes; 5) discussing special treatment issues, such as sharps (e.g., needles, glass, etc.) management and small generator issues; and 6) comparing various management treatment alternatives.

SUMMARY OF FINDINGS

Two of the critical findings of this study are consistent with a comprehensive waste reduction and materials management approach to waste management. First, treatment technologies will continue to be needed for waste management, but they can be preceded and complemented by prevention and pretreatment efforts (i.e., reduction and recycling). Second, while there is no one preferred treatment method, source separation practices (i.e., separating wastes based on the physical, chemical, and infectious characteristics) are key to targeting particular materials/wastes for the most appropriate treatment method.

Other findings of this report include:

. The commercial viability of nonincineration treatment alternatives has increased in recent years due to the increased cost of incineration, the difficulty associated with permitting incinerators, and the perceived desirability of reducing dependence on incinerators given concern over their emissions. Alternative treatment technologies such as autoclaving (steam sterilization) with compaction, microwaving, and mechanical/chemical disinfection are likely to be less capital intensive and have fewer emission concerns than incineration processes. Yet, further investigation of treatment alternatives (e.g., health

[8]These findings, however, will be limited by the nature of the existing &M base and literature from which the findings are drawn. The number Of unreported occupational injury cases, the baseline health status of workers, and the significance of potential exposure routes not yet studied (e.g., aerosolization of substances during treatment, etc.) are crucial unknowns which could strongly impact risk determinations of various treatment technologies.

[9]Treatment methods throughout this report refer broadly to any management technique and processes intended to render the wastes suitable for disposal. Treatment of medical wastes is intended both to render wastes noninfectious and to lead to environmentally sound disposal.

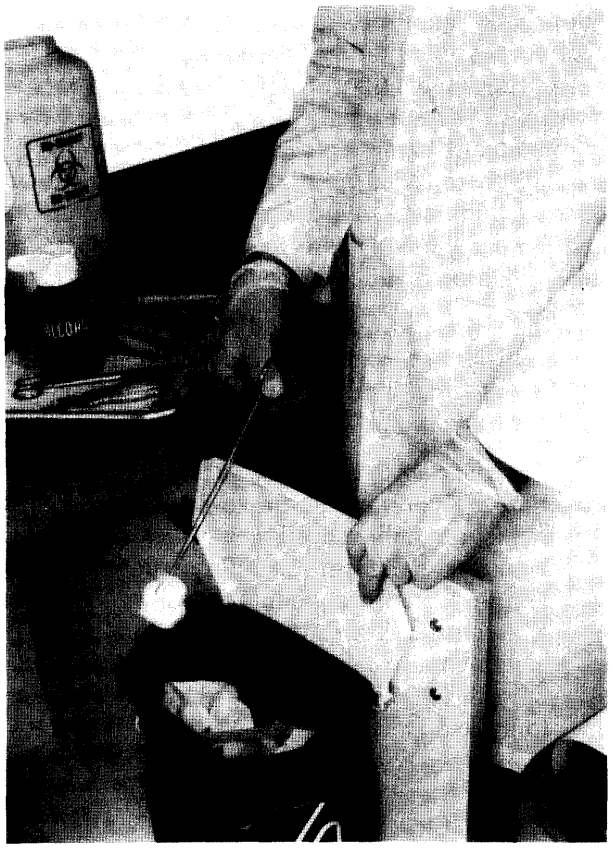


Photo credit: Extrufix, Orlando, Florida

The diversity of the medical waste stream indicates that source separation practices can help target particular materials/wastes to the most appropriate management method, based on the physical, chemical, and infectious characteristics of that waste.

risks) and determination of appropriate performance standards is warranted, as well as consideration of research and development funding to encourage innovative technologies.

- Current regulatory activity at all levels of government tends to encourage incineration either by focusing most of its activity on incineration and/or by identifying it as a preferred treatment method in regulations or guidelines with minimal attention to alternatives. Congress may alleviate concerns over the difficulties associated with introducing alternative treatment technologies by directing EPA to specify approval or certification processes for treatment alternatives capable of rendering infectious medical wastes noninfectious. A program taking these factors into account might help stimulate the development of innovative and improved treatment processes.
- Incineration remains and is likely to continue to remain a primary treatment method for medical wastes for the foreseeable future. Advanced pollution control equipment is becoming a standard part of many new incinerators. An important concern is the impact Federal regulation of air emissions from medical waste incinerators will have when they are finalized in 1991, since stringent regulations have been already enacted by some States.
- New incinerators for a variety of reasons (as noted above) are tending to be larger facilities that operate on a more continual basis than facilities in the past. A number of regional incinerators, either nonprofit/generator or commercial ones, are being planned. Yet some medical waste generators prefer to continue managing their own waste in an effort to maintain greater control over their costs and liability. A number of factors weigh in favor of or in opposition to on-site and off-site management, leaving the particular circumstances of the medical waste generator and the host community to be the main determinants for the type of treatment selected.
- A fundamental policy issue of importance that the Federal Government could address is the extent to which medical wastes are to be regulated on the basis of their potential threat to public health (i.e., infectious nature) and their aesthetic characteristics (i.e., recognizability as a medically related item). That is, Congress could clarify whether the nonrecognizability criteria of MWTA should remain a part of future regulations by addressing this issue either as part of the current Resource Conservation and Recovery Act (RCRA) reauthorization or as part of the evaluation of MWTA upon its expiration in 1991.
- A need exists for further education about the nature of the risks posed by medical wastes and methods for their proper handling and management for health-care workers, other workers at risk, and the general public. These efforts could be undertaken by either or both the health-care community and the government. Such efforts could include instruction for health-care workers and housekeeping staff exposed to medical wastes and incinerator

operating training for workers responsible for medical waste management.

This brief study discusses what is known regarding various medical waste treatment technologies and related management issues. Possible directions for Federal policy and areas where further information to facilitate policy development and improved management are suggested by the study's findings.

POLICY ISSUES FOR FEDERAL ACTION

The reauthorization process for RCRA provides an opportunity to revisit the medical waste issues first addressed by Congress in 1988. In 1991, the completion of the MWTA demonstration program will provide further opportunity to incorporate what is learned from the program and from the mandated studies by EPA and ATSDR into the decision making process for any further Federal action on medical wastes management.

One possible option regarding medical waste issues for Congress to choose is to do nothing in this area once the MWTA demonstration program and agency studies are completed. EPA will set air emission standards for medical waste incinerators and Congress could defer to the Agency, as it has in the past, for any further policy action as considered necessary. Given the general concern over EPA's past reluctance to act on medical waste issues and current efforts at improving waste management practices in the country coupled with concern over State variations in the regulation of medical wastes, this appears to bean unlikely course for Congress.

More likely, Congress will address at least some issues regarding medical waste management as part of the RCRA reauthorization, whatever action may or may not be taken once MWTA expires. 10 Congress could move beyond the current approach to medical waste management and define a more comprehensive approach. A comprehensive approach might incorporate medical waste into the type of waste reduction and materials management approach suggested by OTA (1 16) for MSW. Such an approach could, for example, include determinations on the definition of regulated medical wastes; address waste reduction and recycling goals/objectives; encourage the development and adoption of baseline, uniform standards for each type of treatment method; establish a protocol for approving or certifying new treatment alternatives; and include medical wastes in State waste management plans. In these plans, States could be required to consider waste reduction options, recycling opportunities, capacity needs for treatment, and similar planning issues for medical waste, as they would be required to do for MSW.

Within this more comprehensive approach to medical waste management, or independent of it, a number of other policy issues can be addressed. These include the following:

- Reduction and recycling issues-Greater attention to opportunities for toxicity and volume reduction and recycling of medical wastes would complement the efforts suggested and being adopted throughout the country for MSW. Dissemination of information through the EPA clearinghouse and possibly research and development (R&D) funding, could bring attention to these opportunities.
- Non-incineration treatment technologies—Further investigation of treatment alternatives is warranted, e.g., health risks; need for performance standards (e.g., waste loadings, temperatures); operator and maintenance procedures, etc.
- Incineration treatment issues—Monitoring and operating requirements for medical waste incinerators and operator training and certification requirements could be specified; standards for air emissions and ash management could be established.
- Small generator management-Information and assistance for households and other nonhospital sources of medical wastes could be made available through the clearinghouse for solid waste, which RCRA already directs EPA to establish and the Agency is currently developing.

A number of these issues will need to be addressed by nongovernmental entities, such as hospitals and other generators of medical wastes, the manufacturers of medical supplies, and the waste management industry. In particular, a hospital or medical facility itself can best identify standard operating procedures that affect waste

[10]Note that a number of bills on various aspects of medical waste management have been introduced in Congress, yet the focus Of activity is likely to center on how medical waste issues are addressed in the reauthorization of RCRA.

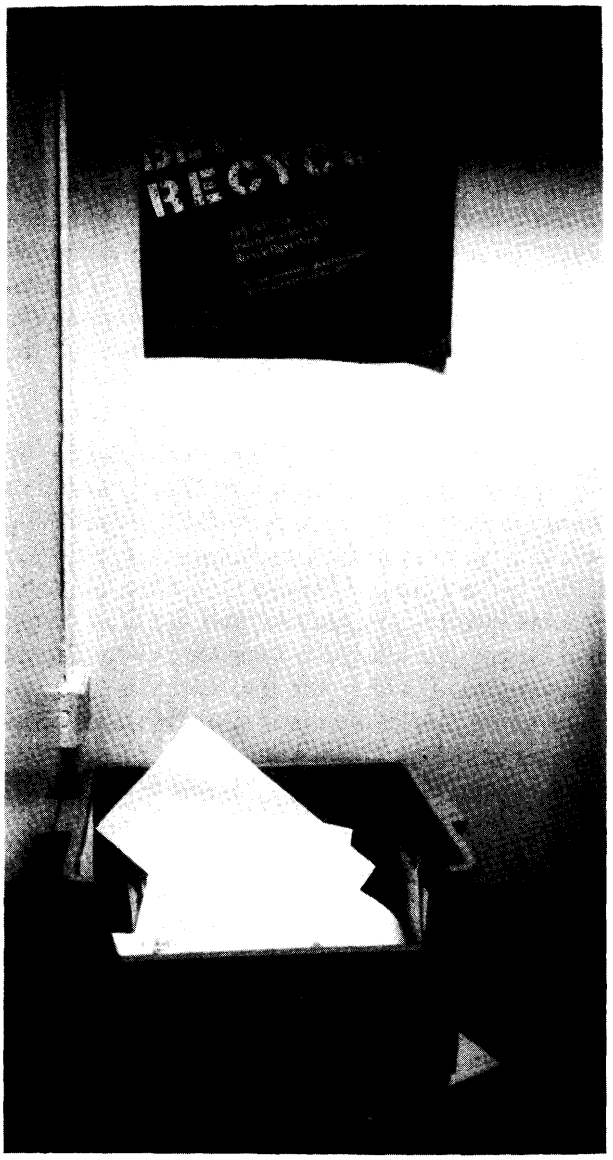


Photo credit: R. Guttman

Careful planning and a comprehensive approach to waste management, which may include recycling efforts, are likely to reap cost savings to a medical facility, as well as environmental benefits for its community.

segregation practices, safe handling of waste materials, and adoption of waste reduction, reuse, or recycling practices.

Medical waste management is a small part of a health-care facility's function, but careful planning and a comprehensive approach to waste management are likely to reap cost savings to the facility, as well as environmental benefits for its community. This type of planning would involve consideration of purchasing practices, use of different types of products, methods of waste segregation, and selection of treatment option(s) based on consideration of the full range of available alternatives. The benefits of such efforts may include cost savings to the facility as well as a reduction in the amount of waste requiring management.

Education efforts regarding the nature of the risks posed by medical wastes and methods for their proper handling and management can also be effectively undertaken by health-care providers-for health-care workers, other workers at risk, and the general public. These efforts can include incinerator operating training and personal protective equipment and instruction for housekeeping staff exposed to medical wastes. The government, waste generators and others involved in medical waste management also can undertake such efforts (see ch. 4).

For example, the American Diabetes Association helps educate diabetic patients on the safe disposal of their syringes (4). The government also could make information and assistance for households and other nonhospital generators of medical wastes more readily available. One possibility is to include such a focus in the clearinghouse for solid waste being established by EPA, as currently required by RCRA. The resources spent on various education efforts would improve understanding of how medical wastes can properly be managed, their associated risks, and would facilitate adoption of improved management practices.

Other more specific issues for which policy clarification by Congress will be useful are whether the nonrecognizability criteria of MWTA will remain a part of future regulations; whether shredding requirements should or will be adopted; and also some specific packaging, transportation, and mailing issues.[11] Of these issues, a fundamental one of critical importance that the Federal Government could address is the extent to which medical wastes are to be regulated on the basis of their

[11] For example, two bills (S. 2393 and H.R. 3386) currently before Congress address the transportation of medical wastes as it is part of the backhauling of waste. The legislation seeks to require the use of dedicated vehicles for some substances, such as medical wastes, to avoid the transportation of food in vehicles used to haul such wastes. The Department of Transportation, however, does not want the authority to regulate backhauling (as the proposed law would grant them) and instead believes the EPA, Department of Agriculture, and the Food and Drug Administration could better take the lead in determining the necessary standards.

potential threat to public health and their aesthetic characteristics.

Considerable expense can be associated with managing wastes (e.g., certain IV tubing) that pose little public health threat but are recognizable as medical items. A health-care organization official recently mused something to the effect that medical waste is probably as much in need of an image consultant as it is in need of regulation. The adoption of regulations that treat wastes purely for aesthetic reasons reinforces a "bad image" for medical wastes, or at least the notion that more of this waste poses hazards than may be true. It may be that the most appropriate treatment criterion with respect to medical waste is the ability of a treatment system to render wastes noninfectious.

Clarifying the definition of regulated medical wastes to include only the waste types considered infectious based on objective criteria may facilitate special management of those wastes that pose the greatest risk to human health without risking" over-regulation" (e.g., special management of wastes for primarily aesthetic reasons). Concerns over such ''needless and expensive' requirements are particularly heard from public officials and generators of medical wastes in rural areas or areas where medical wastes have not been as much of a public concern as they have in the Northeast and other coastal and more densely populated areas. The potential implications of national legislation on areas of the country primarily concerned with the infectious potential (and not appearance per se) of medical wastes need to be carefully considered and balanced against the needs of coastal areas and more densely populated areas. In these areas, the medical waste beach washups and other waste related problems in recent years create entirely different waste management circumstances.

Another important issue centers on addressing whether a "level playing field" exists for all the available treatment alternatives. Congress might facilitate the introduction of new treatment technologies through specification of certification or approval processes for treatment alternatives capable of rendering infectious medical wastes noninfectious. The same testing will not be appropriate for all treatment technologies and determining potential risks and identifying any necessary control measures will also vary depending on the nature of the treatment technology.

A protocol to evaluate new technologies by identifying appropriate tests, establishing standards to demonstrate effective microbial kill, establishing operating parameters and evaluating potential risks could be adopted. Veterans hospitals or other Federal medical laboratories and facilities might also be possible pilot/test sites for new treatment technologies. Funding for the research, development, and testing of alternatives would also encourage innovation and improvement in medical waste management.

It will be an important part of any program regarding the management of medical wastes to include a provision addressing how the adequacy of various treatment alternatives (which in fact might evolve in response to the regulatory program) will be considered. As noted, such a program could provide interim approval or certification status and/or funding for a pilot/test facility to facilitate gathering the information necessary to determine whether routine adoption of the technology would be acceptable. Such a program might help stimulate the development of improved treatment processes.

Characterizing Medical Wastes and Applying a Comprehensive Management Strategy

The Medical Waste Tracking Act (MWTA) of 1988 represents an attempt by Congress to address the problems of beach washups and illegal disposal of medical wastes.[1] A more comprehensive approach to medical waste management, one consistent with the broader waste management strategy evolving nationally, could be formally established if the issue of medical wastes remains part of the current RCRA reauthorization effort. Medical wastes need to be put into a broader frame of reference along with other wastes (e.g., municipal and industrial hazardous and nonhazardous wastes) if we are to establish appropriate levels of protection for humans and the environment. The relative risks posed by all these types of wastes must be considered when determining appropriate management methods for them.

This chapter consists of a brief discussion of the context within which the current Federal approach to waste management for other hazardous and nonhazardous wastes evolved and consideration of the implications of a broader, more comprehensive waste management strategy for medical waste. Appendix A to this report provides a short review of MSVTA, the first major Federal effort to address medical wastes.

MEDICAL WASTE IN A COMPREHENSIVE WASTE MANAGEMENT STRATEGY

The Resource Conservation and Recovery Act (RCRA),[2] passed by Congress in 1976, is the major Federal statute addressing management of the Nation's wastes—hazardous, municipal, industrial, and other types of solid waste, including medical waste.[3] EPA has authority under RCRA to regulate the handling, storage, treatment, transportation, and disposal of all of these wastes. Before passage of MWTA, EPA's activity regarding medical waste issues was mostly limited to distribution of its guidance document for the management of infectious wastes. Other medical wastes were considered to be like any other solid waste and subject to relevant RCRA Subtitle D regulations (114).

OTA finds four key challenges which need to be resolved for medical waste management:

1. better defining/identifying infectious and other medical wastes, to facilitate more consistent and adequate handling and treatment of wastes;
2. better addressing the diversity of generators (e.g., home health care, small doctors' offices, clinics, etc.) to minimize contradictory requirements and inequities they pose;
3. improving the segregation of wastes for their proper treatment; and
4. identifying appropriate treatment alternatives.

The very nature of these issues indicates that a comprehensive, flexible, yet cost-conscious approach is needed for medical waste management. These challenges can be met by a broader approach to medical waste management that emphasizes waste prevention efforts and management of different portions of the medical waste stream based on their physical, chemical, and biological (i.e., infectious) properties. Such a comprehensive approach to waste management is beginning to be applied to hazardous waste and more recently to municipal solid waste (MSW).

[1]Congress also amended the Marine Protection Research, and Sanctuaries Act (also known as the Ocean Dumping Act) in 1988 to increase the penalties for illegal disposal of medical wastes by public vessels (33 U.S.C. 1401 et seq.). See app. A and (115) for discussion of MWTA.

[2]Public Law 94-580 (1976); 42 U.S.C. 6901 et seq. The Solid Waste Disposal Act of 1965 (Public Law 89-272; as amended by the Resource Recovery Act of 1970, Public Law 91-512) was the law by which Congress first established a Federal role in solid waste management. The most recent major revision of RCRA was by the Hazardous and Solid Waste Amendments of 1984 (Public Law 98-616), which did not address medical waste issues in any detail. RCRA is currently in the process of further revision and reauthorization.

[3]OTA (115) recently completed its assessment of municipal solid waste, of which the 1988 background paper on medical wastes was a Part. Currently, OTA is completing a background paper on industrial solid (Subtitle D, RCRA) waste issues (expected to be released in early 1991). Hazardous waste issues have been addressed by several OTA reports (e.g., 112, 113).

It should be noted that the following discussion is based in part on ref. 137.



Photo credit: L. Swanson

Beach washups containing medical debris, such as syringes, helped prompt passage of the MWTA. Subsequent studies indicate the sources of most washups to be related more directly to sewage treatment systems operation than illicit waste management practices.

There is some consensus that at least portions of the medical waste stream can be treated like other MSW. Indeed, in practice this appears to occur. The California Air Resources Board reports, as noted above, that typically 40 percent or more of the waste burned by medical waste incinerators in their State is waste, comparable to MSW in nature (106, 108, 29).[4] Available evidence also seems to indicate that most medical waste poses no more public health or environmental hazard when properly handled than does MSW (109, 56, 107, 139). Yet, when medical waste is incinerated (or treated by some other means) its emissions may be hazardous if not properly controlled (as is the case with any other waste). Thus, basic policy determinations regarding management approaches, and weighing risks and costs, etc., are common to any waste problem.

It is instructive to consider the current trends in hazardous waste and MSW treatment in which there is a movement away from treatment methods that manage indiscriminately mixed wastes and toward source separation programs that encourage management based on the properties of the materials in the wastes (e.g., recyclability, ability to destroy or neutralize, etc.). OTA's assessment of the MSW issue found that environmentally sound waste management requires focusing on how the Nation uses materials from manufacturing through subsequent distribution and disposal (116). On this basis, OTA concluded that,

> A clear national policy on MSW that addresses the use of materials is essential for providing a broader context in which specific MSW programs can be developed and implemented. Waste prevention and materials management should be the foundation of this policy.

The basic steps are: 1) characterizing the waste stream in light of categories used for different alternative treatment options; 2) segregating wastes at the point of origin to facilitate management based on their characteristics; and 3) examining the production of the waste, i.e., looking upstream to consider possible opportunities for waste reduction (in either volume or toxicity) that may include use of different products which are reusable or recyclable or contain less problematic substances for waste treatment.

For example, government agencies and/or the health-care industry could examine prospects for waste reduction in health-care settings (see ch. 2). Although the growth in the volume of medical wastes is not well documented, there is general acknowledgment that the use of disposable in health care has increased significantly in the last two decades. Clearly, in some cases the use of disposable is important for infection control. Yet, those uses driven primarily by economies may need to be reassessed (see ch. 2).

From a management perspective, the presumption held by some regulators and members of interest groups that incineration is the "preferred' treatment option for medical wastes warrants closer examination. Most of the recent regulatory activity for medical waste management at all levels of government tends to focus on incineration and does not usually include specific procedures for the regulatory approval of nonincineration alternatives.

For example, the "treat and destroy or track" requirement of MWTA does not include a process with specific criteria for how the standard can

[4]Based on this type of information, emission data from medical and MSW facilities can be compared, as long as the type and size of incinerator Or other technology and the mix of wastes is taken into account (see ch. 5).

be met by various treatment alternatives, and does not specify how new non-incineration treatment alternatives can be introduced. A number of such alternatives (e.g., several types of disinfection units) are commercially viable and warrant consideration (see ch. 3).

Further, a number of unanswered questions remain regarding incineration, e.g., the nature of emissions and proper controls, the nature and adequate treatment of ash residues, and the cost compared with alternative management methods (see ch. 4). Information on operating parameters, risks, and costs for various alternative treatment methods is also needed. As with the hazardous and solid waste streams, a combination of management options may prove optimal for managing medical waste once the material composition of its components is considered.

That is, landfilling, incineration, and other treatment alternatives, as well as recycling and waste reduction all may be viable management options for medical waste—when it is considered on a waste component basis. Ultimately, this may help to control costs and minimize any hazards associated with medical waste management. This is one way, given the experience gained in regulating other waste streams, that programs to manage medical wastes can be devised wisely and efficiently in order to alleviate public concern, protect workers, and provide environmental protection.

WASTE CHARACTERISTICS AND TYPES—TREATMENT IMPLICATIONS

Examining various treatment options underscores the importance of considering the properties of different types of medical waste and matching them to the capabilities of the treatment technologies. Although the medical waste stream is heterogeneous, the focus of concern is on the portion of the waste stream termed ''infectious, ' and how these wastes are classified (e.g., solid, hazardous, or special) and regulated. The regulated waste stream, i.e., the medical wastes covered by MWTA, includes infectious, potentially infectious, and some wastes identified as requiring special handling. Most estimates are that 10 to 15 percent of medical wastes generated by hospitals are infectious, although this figure can range as high as 80 percent depending on the generator's definition. Determining which portion of medical waste is infectious remains at the heart of definitional issues. How infectious waste is defined can greatly affect the cost of waste management, and ultimately the choice of disposal options (114).[5]

Currently, both aesthetic considerations and health risks posed by medical wastes can lead to the classification of a medical waste as infectious and/or regulated and requiring special management. The State of Washington has defined infectious waste based on risk criteria, particularly the determination of "infectious disease causation potential' (139). A consensus on which medical waste warrants special regulation and management might be forged if the definition of regulated medical waste is based on the potential health risks associated with the waste (i.e., the ability of a particular medical waste-given organism concentration, ability of the waste to penetrate skin, etc.—to pose a risk beyond that associated with MSW to transmit infectious disease).

As noted, no consensus exists on the types of medical wastes that should be designated as infectious or that require special handling, although several categories of wastes are included in most lists (114; also see table 2). Under MWTA (see below), EPA has listed seven types of medical waste (commonly and hereafter refer-red to as "regulated waste types' to be tracked in the demonstration program. These are:

1. microbiological wastes (cultures and stocks of infectious wastes and associated biological that can cause disease in humans);
2. human blood and blood products (including serum, plasma, and other blood components);

[5]Some confusion was created over the Centers for Disease Control (CDC) universal precautions guidance issued in August 1987, that suggested that *all* patients be considered potentially infected with human immunodeficiency virus (HIV) (i.e., the virus which causes acquired immunodeficiency syndrome, AIDS) and/or other blood-borne pathogens and that workers should adhere to rigorous infection-control procedures. In October 1987, CDC issued a joint advisory notice with the Department of Labor further addressing protection against occupational exposure to Hepatitis B (HBV) and HIV. After these advisories led to a great inflation of the amount of waste designated as infectious, the CDC issued a clarification in August 1988, indicating to which types of secretions and circumstances its recommendations applied and that CDC did not intend for generators to alter waste management procedures, but only meant to protect health-care workers. In May 1989, the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor issued a proposed job health standard for protecting health-care workers from blood-borne diseases.

Table 2—Types of Wastes Designated as Infectious by Various Entities

Waste category	EPA/ MWTA	EPA[a]	CDC	MA	CA	IL	NY	SC	WI	Percentage of hospitals
Microbiological [c]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	99.0
Human blood and blood products	Yes	Yes	Yes	Yes	No[d]	Yes	Yes	Yes	Yes	93.7
Isolation wastes	Yes	Yes	Optional [e]	Yes	Yes	Yes	Yes[f]	Yes	No	94.4
Pathological wastes [g]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	95.6
Contaminated sharps [h]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	98.6
Contaminated animal carcasses, body and bedding	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	90.1
Uncontaminated sharps	Yes	No	No	Yes	No	No	Yes	No	No	N/A
Other contaminated wastes:										
Miscellaneous laboratory wastes		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	88.8
Surgery and autopsy wastes		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	83.2 &91 .9, respectively
Dialysis unit wastes		Optional[i]	No	Yes	Yes	No	Yes[f]	No	Yes	83.4
Equipment		Optional[i]	No	Yes	Yes	Yes	Yes[f]	No	Yes	N/A
Any other infectious waste		No	No	Yes	Yes	Yes	Yes	Yes	Yes	Varying percentages

[a] Based on recommendations in EPA Guidance Document (U.S. Environmental Protection Agency, *Guide for Infectious Waste Management*, EPA/530-SW-86-014 (Washington, DC: May 1986); see discussion in U.S. Congress, Office of Technology Assessment, *Issues in Medical Waste Management—Background* Paper, OTA-BP-O-49 (Washington, DC: U.S. Government Printing Office, October 1988).

[b] Percentage of hospitals designating this waste category, according to a survey completed for the American Hospital Association. W. Rutala, W.W. Odette, and G. Samsa, "Management Of Infectious Waste by U.S. Hospitals," Journal of American *Medical* Association 262:1635-1640, 1989.

[c] Such as cultures and stocks of infectious agents.

[d] Human blood and blood products that are proven to contain pathogens arae subject to California's infectious waste law and regulations.

[e] CDC recommends that this waste be treated according to hospital policy.

[f] The New York State Commissioner of Environmental Conservation may exclude this category.

[g] Such as human body parts, tissues, fluids, and organs.

[h] Such as syringes, needles, scalpel blades, and 91a=.

[i] EPA's 1986 guidance states that the decision to handle these wastes as infectious should be made by a responsible, authorized person or committee at the individual facility.

SOURCE: Office of Technology Assessment, 1990; based on U.S. General Accounting Office, *Medical* Waste Regulation: Health and Environmental Risks Need To Be Fully Assessed, GAO/RCED-90-86 (Washington, DC: March 1990).

3. pathological wastes of human origin (including tissues, organs, and body parts removed during surgery or autopsy);
4. contaminated animal wastes (i.e., animal carcasses, body parts, and bedding exposed to infectious agents during medical research, pharmaceutical testing, or production of biologicals);
5. isolation wastes (wastes associated with animals or humans known to be infected with highly communicable diseases);
6. contaminated sharps (includes hypodermic needles, scalpels, broken glass); and
7. uncontaminated sharps.[6]

Other waste categories that EPA had to consider for inclusion in MWTA demonstration program are: wastes from surgery or autopsy that were in contact with infectious agents (e.g., sponges, soiled dressings, drapes, surgical gloves, drainage sets); dialysis wastes that were in contact with blood; discarded medical equipment and parts that were in contact with infectious agents; and laboratory wastes that were in contact with infectious agents (e.g., laboratory coats, slides and cover slips). EPA determined that potentially infectious items from these waste categories are covered by the other seven regulated waste types. It is interesting to note that according to a recent survey sponsored by the American Hospital Association, the vast majority of the 441 randomly selected hospitals designated six of the seven categories above as infectious (the exception being unused sharps) (95).

Wastes within each of these regulated waste type categories can have different chemical (hazardous, radioactive, or nonhazardous) and physical (liquid, gas, or solid) characteristics that are important to consider in selection of the most appropriate treatment method. Clearly, different types of medical practices by physicians, types of hospitals, and different departments within a hospital generate different types and quantities of the regulated waste types (123, 29) (see table 3). Therefore, it is reasonable to assume that just as hospital type and size and occupancy rate are important determinants of generation rates of medical wastes, they are also key factors affecting the chemical and physical make-up of the wastes. That is, general medical and surgical hospitals will generate a different quantity and mix of wastes than psychiatric or other specialty hospitals (e.g., chronic disease, orthopedic, and eye/ear/nose/throat hospitals).

Chemical Characteristics

Hazardous Constituents

Waste from a medical facility may contain cytotoxic chemicals, laboratory solvents, toxic metals, low-level radioactive waste, or waste contaminated with human pathogenic microorganisms. Cytotoxic chemicals are hazardous pharmaceuticals used in chemotherapy, and seven such compounds are on the RCRA ''U' list of hazardous waste.[7] This means that they cannot be disposed of in bulk quantities in medical waste incinerators without a RCRA hazardous waste incinerator permit. It is also true that these RCRA hazardous wastes could not be treated by most nonincineration treatment methods. Yet, given that these substances are usually encountered as "trace" contaminants, rather than "bulk wastes," they are not managed as RCRA hazardous wastes, and can legally be disposed of with other medical wastes.

Laboratory solvents and other types of hazardous chemicals are commonly found in medical wastes, and many of these are also listed as hazardous wastes under RCRA.[8] Although these wastes should be managed separately from other medical wastes as RCRA hazardous wastes, like cytotoxic compounds, sometimes they are so intimately mixed with medi-

[6]See GAO (134) for a more complete discussion of the EPA's determinations for inclusion and Specification of the different waste types.

[7]These are: chlorambucil, cyclophosphamide, duanamycin, melphalan, mitomycin, stretozotocin, and uracil mustard. These cytotoxic compounds are a small fraction of all cytotoxic agents. The total amount of cytotoxic compounds incinerated is not known and little is known of the potential threat from cytotoxic emissions.

Indeed, data for cytotoxic emissions is lacking and conditions necessary to destroy cytotoxic compounds arc not known. A conservative assumption is that 1,800 °F (1,260 K) would ensure complete destruction of cytotoxic compounds, although destruction is also dependent on residence time and mixing (12, 41). As part of its testing program (at two incinerators) for developing standards for ncw medical waste incinerators, EPA is conducting tests to determine the destruction efficiency of the two test medical waste incinerators of hexochlorobenzene as a surrogate for cytotoxic chemicals (the tests will be conducted at a secondary chamber temperature of 2,000 °F) (41).

[8]Hazardous solvents typically found i, medical waste include: acetone, 2.butane], butyl alcohol, cyclohexane, diethyl ether, ethyl acetate, ethyl alcohol, formaldehyde, heptane, hexane, methyl alcohol, methyl cellosolve, pentane, petroleum ether, 2-propanol, sec-butyl alcohol, tert-butyl alcohol, tetrahydrofuran, and xylene (12). Many of the chemicals used as laboratory solvents and all but the seven chemotherapeutics listed as hazardous waste can be disposed of legally through the sewer system (141).

Table 3—Percentages of Waste Types Produced at Different Medical/Health-Care Facilities in the State of Washington

	Type of facility										
All cases	Total	Funeral	Nursing	Vet	Lab	Surgery centers	Hospital	Clinic	Dental	Research	Medical
Wastes produced (*) ... , ...	100% (350)	1 00% (32)	100 "/0 (43)	1 00% (49)	1 00% (25)	100"/0 (8)	100"/0 (51)	100% (60)	100% (32)	10070 (17)	10070 (33)
Wastes with excretions/secretions , .,	75		91	84	64	63	96				70
Microbiological , ., ...	42	0	16	41	44	25	92	57	3	65	42
Human blood and blood products	56	88	23	2	88	38	96	63	44	53	64
Animal blood and blood products	15	0	0	69	12	0	10	0	0	59	3
Pathological . . . . . , ., ., ...	44	28	5	86	32	50	88	32	31	24	30
Sharps	94	94	98	96	92	100	98	87	91	88	100
Wastes from surgery	64	69	16	92	8	88	98	67	78	12	76
Dialysis unit wastes ., ...	7	19	0	0	0	0	25	5	0	6	3
Contaminated animal carcasses/ bedding . . . . . ., ...	14	3	0	76	0	0	4	0	0	47	0
Isolation patients' wastes ., ...	32	47	77	37	8	0	78	5	0	0	6
Radioactive wastes ... , ., ., ...	15	0	0	0	40	0	49	10	0	53	9
Chemotherapy wastes	18	9	2	10	12	13	69	15	0	0	18
None of the above ., ...	3	3	0	0	8	0	2	10	3	6	0

(*) percentages may not add to 100 percent because of multiple responses.

SOURCE: Washington State Department of Ecology, Solid and Hazardous Waste Program, "Report to the Legislature: Washington State Infectious Waste Project and Attachments" (Olympia, WA: Dec. 30, 1989).

cal wastes that separation is impractical.[9] When hazardous materials are mixed with infectious wastes in this way, the hazardous portion needs to be the component that is given primary consideration for proper treatment. Some generators prefer a treatment method (e.g., incineration) that is practical for both hazardous and infectious materials so that only one treatment form is required. Alternatively, the infectious nature can sometimes by addressed through thorough disinfection before being sent for hazardous treatment to avoid exposure to infectious agents during the handling process (43).

These substances may be precursors in the formation of dioxins (dibenzo-p-dioxin, PCDD) and furans (dibenzofuran, PCDF), suspected carcinogens, when chlorine is present during incineration (12). Metals that can be toxic, such as lead, cadmium, chromium and mercury, are present in medical waste. One study completed by the University of California at Davis concluded that plastics in the waste contributed most of the lead and cadmium (12). Although lead was found in many materials, plastics were the primary source. Both cadmium and lead are components in common pigments and are used as thermo- and photo-stabilizers in plastics, such as may be used to color red bags used for infectious waste (12).

Low-Level Radioactive Wastes

Low-level radioactive wastes (LLW) are produced in health-care settings from administering radiopharmaceuticals and performing nuclear medicine procedures and radio-immunology procedures. In fact, medical and research facilities produce less than 5 percent of the total volume of LLW generated in the United States (1 17). It should be noted that unlike radioactive materials used in powerplants or the production of weapons, medically useful radioactive tracers, which are extremely valuable in diagnostic procedures and medical research (e.g., testing new drugs), usually have a very short half-life (1 17). That is, typically, half of the material decays to a nonradioactive form in hours to days. Hospitals usually do not store LLW with isotopes with half-lives greater than 8 days given the significant amount of storage space this would involve (117, 73). Currently, there are only three disposal sites for storage of LLW in the United States.[10] The temporary closure of two of these sites in 1979 set in motion Federal efforts to encourage States to establish more sites and spurred medical and health-care facilities to devise a variety of new reduction and management strategies for LLW (see box A).[11]

Biological Characteristics

Pathogens in Wastes

Pathogens in medical wastes include a wide range of bacteria, viruses, and other microorganisms (e.g., mycobacteria, yeasts, fungi, parasites, and rickettsia) that are sufficiently virulent to infect a human body if they are given an exposure route (e.g., a puncture or an open wound) (12,3).[12] Clearly, pathogens are also present in MSW (e.g., contributed by disposable diapers, sanitary napkins, tissues, etc.), although the likely higher concentrations of pathogens in medical waste and the level of pathogenicity of organisms found in health-care institutions and their increased resistance to antibiotics may make them a greater threat for those who handle the material and may also introduce the possibility of public health concerns (43).

The important issue is the viability of the pathogens during treatment and disposal and their potential to transmit disease. Some degree of pathogen survival in an MSW landfill is expected, for example, but the likelihood of pathogens migrating from a properly operated landfill is considered extremely low, based on available research (110, 138, 116). Even so, there have been few scientifically designed experiments to measure for pathogens, e.g., in leachate or waters downstream from a landfill (41).[13]

[9]That is, radioactive tracers which are commonly used for diagnostic purposes arc commonly mixed with solvents during the extractive procedures and should be handled as hazardous waste, according to EPA (141).

[10]These are in Washington State, Nevada, and South Carolina. Not surprisingly, these States object to being the Nation's only disposal sites.

[11]Congress passed the Low-Level Radioactive Waste Policy Act in 1980 (later amended in 1985), which makes each State responsible for providing disposal capacity for its own LLW and encourages States to form compacts (which can exclude wastes from nonmembership States) to provide disposal capacity. Too little waste is generated to justify a need for a LLW disposal site in every State (see 117).

[12]Medical wastes and MSW can Contain such organisms as: staphylococcus aureus, candida albicans, pseudomonas, clostidium perfringens, staphylococcus cpidermidis, and respiratory streptococci (12).

[13]For example, microorganisms such as Salmonella and Hepatitus virus can be carried in water, and can survive well (43).

Box A—Management of Medical Low-Level Radioactive Waste (LLW)

Medical LLW is treated in several ways, depending on the physical form of the waste (e.g., liquid or solid) and the type and quantity of its radioactivity. The medical LLW with short-lived radionuclides (i.e., less than 8 days) in low concentrations is typically stored until its radioactivity is below detectable levels. The waste can then be disposed of as nonradioactive waste. Certain liquid medical LLW that meets limits established by the U.S. Nuclear Regulatory Commission (NRC) for radioactivity concentration and volubility in water can be disposed of through the sewer. Certain solid medical LLW (e.g., liquid scintillation counting media and biological) can be disposed of without regard to its radioactivity, where the radiological hazard is considered small, but the nonradiological hazards warrant special handling and disposal. [1]The NRC considers controlled incineration of low-activity medical LLW to be adequate treatment because any radioactivity released during the burning is well below accepted environmental levels. Medical LLW, which cannot be stored for decay, disposed to the sewer, or incinerated, is typically land disposed.[2]

The NRC distinguishes four classes of LLW: Class A Waste (contains low levels of radiation and requires no shielding to protect workers; decays in less than 100 years and represents about 97 percent of LLW); and Class B, Class C, and Greater Than Class C (all three of which require shielding and can remain harmful for 300 or more years). In addition, LLW that is mixed with hazardous waste is referred to as ''mixed waste" (e.g., organic liquids, such as scintillation fluids used in diagnostic tests, comprise the largest volume of mixed LLW). Mixed LLW is regulated by both the NRC and the EPA; at this time there are no licensed facilities to accept mixed LLW (117).3

Since 1980, total LLW volumes have been reduced by 55 percent, and estimates for reducing medical LLW could be 70 percent or higher (117, 140, 136). This reduction is due to efforts by generators to reduce volume, costs, and risks associated with LLW management. The waste min imization techniques include improved management (i.e., segregation of nonradioactive from radioactive waste), substitution of nonradioactive materials, and operational practices to prevent materials from becoming contaminated (1 17, 24).[4] Although volume reduction to date has already reduced the amount of LLW requiring disposal, the NRC and Agreement States have considered reclassifying some LLW to a category for which no special handling or management would be required. Previously, public concern over potential health risks associated with any such reclassification has worked against adoption of any national proposal to reclassify LLW in this way. Recently, however, the NRC announced a controversial new policy that deregulates certain low-level radioactive wastes considered nonhazardous. This so-called "below regulatory concern" (BRC) waste would include such items as trace amounts of radioactive material and mildly contaminated bodies of laboratory animals, which health-care and medical research laboratories could dispose of with municipal solid waste (135).

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[1]That is, such waste would be managed as a hazardous waste if other components of the waste are hazardous or as medical waste if the waste is non-hazardous (1 17, 70, 24)

[2]Estimates are that two 10-foot-deep trenches, each about the size of a football field, are required to meet the amount Of LLW from medical and health-care settings annually in the United States. However, the exact amount of medical LLW is not known (l). (See ref. 117 for a detailed discussion of these site requirements, the efforts to date to form compacts, and other issues regarding LLW management.)

[3]An exception of this statement is scintillation fluids. For the most part, these substances can be treated (e.g., incinerated) because the concentration of radionuclides in them falls below limits set in the NRC's Biomedical Rule (10 CFR, Part 20.306). Other higher concentrated medical mixed wastes, however, are left with no treatment or disposal options.

[4]Interestingly, medical LLW is one area Of waste management for which the medical profession has been encouraging governmental action to ensure the availability of disposal sites, and thereby the continued use of radioactive isotopes. For example, the American College of Nuclear Physicians has "stIongly' encouraged officials of all levels of government to achieve a timely resolution of the [LLW issues], stressing public safety, economy, and preservation of all the benefits society enjoys that depend on radioactive isotopes" (19).

A risk evaluation completed in King County, Washington (Seattle area), concluded that reduction in the risks posed by medical waste will best be achieved by eliminating modes of transmission between humans and the pathogens in the wastes (111). Pathogens are easily destroyed when exposed to the mean gas temperature and residence times encountered in incineration. The main potential routes of exposure of concern, then, are through escapes of gases containing pathogens during loading, and pathogen survival in the ash or air emissions due to poor operating conditions (see discussion in 134). To date few test results have been published documenting pathogen survival after incineration, and further study has been recommended (1 34). EPA is planning to address the issue of potential pathogen survival in the incineration cycle in its current study of medical waste incineration (33). The results of

Table 4-Characteristics of Medical Waste

Waste component	Bulk density as fired (lb/cu.ft.)	Moisture content as fired (weight percent)	Heating value as fired (Btu/lb)
Human anatomical ... ,	50-75	70-90	800-3,600
Plastics ,	5-144	0-1	13,860-20,000
Swabs, absorbents ., .,	5-62	0-30	5,600-12,000
Alcohol, disinfectants	48-62	0-0.2	10,980-14,000
Infected animals	30-80	60-90	900-6,400
Glass ... , .., ,	175-225	0	0
Bedding, shavings, paper, fecal matter	20-46	10-50	4,000-8,100
Gauze, pads, swabs, garments, paper, cellulose	5-62	0-30	5,600-12,000
Sharps, needles .,	450-500	0-1	0-60
Fluids, residuals	62-63	80-100	0-2,000

KEY: 1 lb/cu.ft. = 16.03 kg/m³
1 Btu/lb = 2.324 J/g

SOURCE: T. Milburn, "Biomedical Waste Incineration BACT Application Considerations, " Proceedings of the Third National Symposium on Infectious Waste Management, Chicago, IL, April 1989, as cited in R. Barton, G. Hassel, W. Lanier, and W. Seeker, State of the Art Assessment of Medical Waste Thermal Treatment EPA Contract 68-03-3365 and ARB Contract A832-155 (Irvine, CA: Energy & Environmental Research Corp., 1989).

this effort will be reported in the Agency's final report to Congress, although EPA anticipates that further studies on the issue beyond this effort maybe warranted (14 1).

Disinfection rates for nonincineration treatment alternatives can also be high, if the treatment system is properly designed and operated. A source of general concern and confusion is the extent to which various treatment alternatives ''disinfect' medical wastes. The efficacy of a treatment method should be demonstrated by development of an appropriate biological testing program. It appears reasonable that the degree of disinfection not be required to exceed microbial and virulence levels that may generally be found in MSW (111).

Physical Characteristics

The basic physical forms of medical wastes (solid, liquid, and gas) should be taken into account for their handling and management. Segregation of wastes by health-care facilities into types based on these physical states is likely to occur, e.g., liquid wastes, non-sharp/solid wastes, sharp wastes (see tables 4 and 5).

Both physical characteristics (e.g., heat value and moisture content) of waste components and the biological make-up and chemical (elemental) composition of the waste are important determinants of the most appropriate treatment technology and have important impacts for that treatment. Despite the fact that medical waste is heterogeneous in its physical and chemical nature, the waste is rarely managed initially as a mixture of all the wastes from the facility. That is, it is likely that a medical facility will collect wastes from various departments separately (i.e., computer printouts are collected from the accounting department; kitchen waste, patient waste, etc. are collected separately), although they may be mixed for treatment (e.g., incineration) (12, 139).

Table 5-Comparison of the Composition of Medical and Municipal Waste

Waste component	Amount in waste, percent by weight: Medical waste	Municipal waste	Hazardous waste[a]
Dry cellulosic solids	45.1	54.2	0
Wet cellulosic solids	18.0	12.2	0
Plastics	14.2	7.4	12
Rubber	0.7		
Solvents			58
Noncombustibles	20.4	26.2	
Pathological	1.6		
Heating value (Btu/lb)	6,000	4,335	6,030

[a]For a typical commercial incinerator accepting a broad range of wastes.
1 Btu/lb = 2.324 J/g

SOURCE: D. Campbell, "Hospital Waste Management in Canada," Proceedings of the National Workshops on Hospital Waste Incineration and Hospital Sterilization, U.S. Environmental Protection Agency, San Francisco, CA, May 19843, as cited in R. Barton, G. Hassel.W.Lanier, and W. Seeker, State of the Art Assessment of Medical Waste Thermal Treatment, EPA Contract 68-03-3365 and ARB Contract A832-155 (Irvine, CA: Energy & Environmental Research Corp., 1989).

Given the important impact chemical characteristics of wastes can have on the effectiveness of various treatment technologies to safely manage medical waste, it appears sensible to keep wastes separate based on their physical and chemical properties, at least as carefully as possible into hazardous, solid, and regulated medical/infectious waste categories, to ensure the wastes receive appropriate treatment/management. This will be true whether incineration or nonincineration treatment

technologies are used. It will also facilitate efforts to recycle wastes when feasible and identify opportunities for waste reduction.

EPA adopted as part of its regulations under MWTA (40 CFR Part 259) segregation requirements to control and reduce costs for waste disposal and minimize worker exposure to certain medical wastes. The Agency reports, however, that facilities in MWTA demonstration program base their segregation policies primarily on the basis of convenience and barriers associated with reeducating their staff to change management practices (141). A recent study commissioned by the New York City Health & Hospitals Corp. and conducted by Waste Tech, finds that facilities required to comply with MWTA could reduce the cost and volume of their waste management through more careful segregation and reduction practices (62, 63). Waste management companies also report that segregation at the point of generation is key to containing handling and treatment costs, as well as assisting in appropriate recycling opportunities (43) (see ch. 4).

Chapter 2

Before Treatment: Waste Reduction and Recycling

Waste management concerns now confronting the medical waste generator are largely reflective of the general movement toward minimizing the quantity of waste warranting disposal. Effective management of medical waste incorporates a waste reduction and recycling component where appropriate. These activities should be fostered via policy incentives.

This chapter explores the implications of applying a waste prevention and materials management approach (ch. 1) to medical wastes by considering "before treatment" approaches to controlling medical wastes. This exploration includes a discussion of careful on-site planning, and waste reduction and recycling opportunities in health-care facilities.

BEFORE-TREATMENT APPROACHES

Lessons from the management of other waste streams, notably hazardous waste and MSW, indicate that (as noted in ch. 1) a sound control strategy for waste management follows the basic steps of characterizing the waste stream in light of different treatment alternatives, segregating some wastes to facilitate management based on these characteristics, and looking "upstream" to discover any opportunities to reduce the volume and/or toxicity of waste. Achieving this strategy requires some form of planning to garner the necessary information for reduction and management decisions.

The value of on-site management plans or strategies appears to be gaining recognition as more medical and health-care facilities grapple with how to respond to increasingly complicated regulations for waste management (94). Waste audits of some form are becoming more common in hospitals and other medical institutions. The advantages of these waste audits or more comprehensive plans for a facility include using the information they provide not only to devise a strategy for compliance with environmental requirements, but also to determine the most cost-effective means to meet requirements without compromising the quality of patient care and to identify waste reduction, reuse, and recycling activities as well as other management options that could be adopted.

Every facility must tailor its own strategy based on its characteristics, but several areas should be addressed in any attempt to analyze waste options. First, the definition and segregation of wastes should be examined because facility standard operating procedures (SOPS) for waste segregation have a direct impact on type and cost of medical waste treatment. For example, sometimes when a facility designates "surgery waste" as infectious waste all waste from that department is managed as infectious waste, some of which could be managed as noninfectious (e.g., paper from the administrative area).

Second, the types of products and packaging (e.g., for wastes) used in the facility and their impact on the waste stream can be considered, without compromising infection control goals. For example, woven linens may be substituted for some applications of disposal linens with little risk of increased infection potential; and, based on preliminary data from the New York City Medical Waste Study, considerable reduction in the volume of waste and significant cost savings (see box B) (62, 63, 94). Careful purchasing might help reduce the level of toxic emissions from an incinerator. Finally, the types of on-site versus off-site disposal options available to a facility need to be considered from handling and management perspectives and their costs and risks compared.

WASTE REDUCTION

Source reduction, or prevention, of waste is defined by OTA as "activities that reduce the toxicity or quantity of discarded products before the products are purchased, used, and discarded" (1 16).[1] Source reduction can be achieved by: 1) manufacturers considering waste issues in designs of current and planned medical and health-care products and their packaging; and 2) consumers of medical and health-care products (e.g., hospitals) directing their purchasing decisions, product use, and the discarding of products toward waste reduction goals. The two fundamental characteristics of wastes that are the focus of reduction efforts are: toxicity, i.e., eliminating or finding benign substitutes for substances that pose risks when they are discarded; and

[1] A basic distinction is made between prevention and management, the latter occurring after waste is generated.

Box B—Disposables: Infection Control and Waste Management Implications

It appears that the use of disposable can be carefully tailored, from an infection control perspective, to those procedures where disposable have the greatest benefit (e.g., isolation situations). Based on a literature search of research to date, OTA found that handwashing is widely considered to be the most important barrier to transmission of infections (119, 53, 59, 61). A clear understanding of modes of infection transmission and the factors that affect it can ensure that the most effective infection control practices are undertaken (53, 59,98, 105). Measures to control infections include handwashing, the use of sterile disposable items, and other measures (e.g., closed urinary drainage, intravenous catheter care, nontouch dressing techniques, and proper care of respiratory equipment and perioperative chemoprophylaxis) (119, 120, 53).

In some cases, the benefits of isolation (in which typically disposable, nonwoven polypropylene gowns and nonsterile latex gloves are used) have been demonstrated for reducing the incidence of nosocomial bacterial and fungal infection, particularly in cases of prolonged (more than one week) intensive care for a patient (64). Yet, often the sources of infections in hospitals are discovered to be related to misuse of medical equipment and person-to-person transmissions. In one London hospital, the investigation of a number of incidents of cross-infection with an antibiotic resistant infection (Klebsiella aerogenes) led to the conclusion that, 'While many units practise [sic] almost ritual cleansing of selected equipment, and rely heavily on disposable, there are often circumstances when the misuse of simple ward equipment [in this case, contamination of portable suction apparatus] becomes an accepted routine with inevitable consequences" (37a).

Some infection control measures are proven and standard practices for every hospital, while others are supported by less extensive studies, and some proposed measures are not supported by study data (e.g., floor disinfection). A disposable item maybe in any one of these categories regarding its value as an effective infection control measure depending on the particular item and its use. Studies have found, for example, that nonwoven disposable gown and drape fabrics were no better barriers to infection than reusable, woven, cotton gowns and drapes; and, in point of fact, the protective value as well as the transmission potential of gowns, shoe covers, and even masks has been questioned (50, 16, 59).[1] Potential volume reduction of disposable linens and medical apparatus could be considerable, perhaps between 30 to 60 percent depending on the specific health-care facility (63).

With other disposable items, e.g., some catheters and syringes (by diabetics), reuse is not a simple yes-or-no issue. Studies to date indicate that morbidity associated with reuse of cardiac catheters, for example, is low (46, 37, 60). With regard to the reuse of disposable syringes, it appears both safe and practical for diabetics to use disposable syringes and needles for more than one injection (4, 52, 23, 90, 46).[2]

Nonetheless, the practicality of reuse, given liability concerns and standard operating procedures for a particular health-care facility, may preclude reuse of particular medical items at an institutional level.[3] Certain disposable items though are advantageous over reusable items for various reasons including controlling infection, saving labor costs for processing, and minimizing exposure to hazardous chemicals used in chemical sterilization processes. The use (and reuse) of disposable can be considered on an item by item basis, in light of how they will be used, including consideration of infection risks and other factors associated with those risks. Some institutions are beginning to examine the opportunities for use of fewer disposable and other waste reduction options (see below).

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[1] In any case, one study reports that linen poses a higher infection risk to laundry workers than to patients (21a).

[2] It should be noted that these studies focused on the reuse by the same patient, i.e., a diabetic, using the same syringe. Diabetic patients who used the same plastic disposable syringe (up to 7 days) were not found to develop infection at the site and little or no contamination of the syringes was found (23, 90).

The American Diabetes Association (ADA) in its Position Statement on Insulin Administration states that although manufacturers of disposable syringes recommend that they be used only once, most insulin preparations have bacteriostatic additives to inhibit growth of bacteria commonly found on the sic@ and generally "it appears both safe and practical for the syringe to be reused if the patient so desires" (4). The syringes must be discarded when the needle is dull or if it becomes contaminated in some way. The ADA statement also discusses the importance of such practices as good personal hygiene and proper handling of syringes (i.e., procedures to recap a syringe safely) by patients.

[3] The potential for increased liability of a health-care facility using nondisposables v. disposable for different medical applications has been raised. OTA asked only one insurance company about this concern and was told that insurance companies insure for negligence and distinguish between real and perceived risk in such a way that the use of disposable v. nondisposables would not usually matter from a liability perspective. It was also noted that insurance companies do attempt to ensure that proper procedures are followed to help keep risks as low as possible (15).

quantity, i.e., changing the design or use of products to minimize the amount of waste generated when they are discarded.

For waste reduction, reuse, or recycling to occur within a medical facility, a waste audit that emphasizes characterization of the waste stream and development of a plan delineating necessary segregation techniques and education/training of the approach to be taken to the employees of the health-care facility is necessary. Currently, most health-care facilities resist waste segregation because of its perceived inconvenience and the difficulty of ensuring staff compliance. The increased costs associated with new regulatory requirements, however, are creating an economic incentive for greater waste segregation by health-care facilities.

From both volume and toxicity perspectives, the use of plastics in society is a focus of waste management concern. EPA's recent report on plastics in MSW found that plastics production has had an average annual growth of 10 percent for the last 30 years (132). The report also noted that "source reduction and recycling are the best way to reduce potential environmental impacts from plastic wastes" and discusses a number of activities EPA will undertake toward these ends. A higher percentage of plastics is contained in medical wastes than in MSW, approximately 20 percent (by weight) in medical wastes (and perhaps higher)[2] and slightly under 10 percent (by weight) in MSW (1 14, 116).[3] The medical community is projected to consume 2.4 billion pounds annually by 1994 (13).

As in general public use, plastics are utilized for both products and packaging. While single-use disposal plastic items are often preferable from an infection control perspective, other forces have stimulated the use of these products. For instance, to facilitate pricing patient procedures individually, disposable products are individually wrapped to make bookkeeping easier both internally and for third-party reimbursement. Certain internal practices within health-care institutions reduce waste even if they were not initially developed for this purpose. For instance, inventory programs that keep packaging and corrugated cardboard boxes out of the health-care facility, and often times discourage single-item packaging, can have a positive effect.



Photo credit: R. Guttman

Corrugated cardboard-including that used to specially package regulated medical waste s-can comprise a significant portion of a hospital's waste stream. Some hospitals have purchased balers to facilitate handling and marketing of reclaimed cardboard.

Procedural trays that are prepackaged by distributors reduce individual packaging and put all necessary products for a procedure within a single container.

The type of plastic used and its impact on waste treatment is one example of how waste reduction efforts focused on reducing certain emissions can link pretreatment and treatment management efforts. The higher concentrations of hydrogen chloride (HCl) in emissions, on average, from medical waste incinerators compared with MSW incinerators may be due to the higher levels of polyvinyl chloride (PVC) plastics in medical wastes. Almost all of the chlorine in these wastes is converted to HCl during the combustion process (assuming a high combustion efficiency). In this way, chlorinated plastics may contribute to the high emission rates of HCl and

[2]One recent survey of New York City hospitals found 26 percent of medical waste to be plastics (63).

[3]Yet, given that medical waste is a small percentage of MSW, it is likely that the *total* release of HCl from medical wrote incineration is comparably lower (despite the higher concentration). In a local area, however, it could be a significant source of such emissions.

possibly the formation of dioxins (particularly if combustion efficiency is low) (114).

PVC plastics were reported to account for 9.4 percent of the weight of infectious wastes in one study of two Houston hospitals (cited in 139).[4] Concerns over hydrogen chloride generation through on-site incineration, as well as off-site, have begun to put pressure on the producers of plastic medical products to switch from polyvinyl chloride plastic to one that does not carry the same type of environmental concerns, such as polyethylene (51, 43). Unfortunately, because of certain physical characteristics, the PVC plastic is more desirable in certain products. Increased efforts to find alternate materials for products such as intravenous tubing should be encouraged. For other products, such as slide holders, trays, and garbage bags, manufacturers may be able to easily substitute materials (139, 43).

Sometimes there can be a direct tradeoff between the potential environmental harm caused by one management practice versus another. For example, the issue of whether using disposable or reusable items is "better" can be difficult to determine. It will depend on which particular goal (e.g., infection control, convenience/labor savings, cost savings, safe waste management) is deemed most important regarding the product's use. One example of where such a determination has to be made regards the use of products and equipment generating chlorofluorocarbon (CFC) emissions, which are used by the medical and health-care industry to sterilize reusable items for patient procedures.

The medical and health-care industry is responsible for less than 4 percent of the total amount of CFCs released to the atmosphere. Given the concerns over the association of CFCs with ozone depletion and possible global warming effects, the American Hospital Association has recommended that hospitals reduce consumption of all CFC-based products and chemicals used for sterilization purposes.[5] This reduction can be achieved through the use of disposable, but any significant growth in the use of plastics containing CFCs might negate overall CFC reduction. It maybe that other solutions would avoid greater contributions to the medical and solid waste streams, e.g., the greater use of steam sterilization or other substitutions for CFC-dependent sterilization systems, or use of non-CFC, recyclable plastics (76, 129).

The increased use of disposable in health-care settings is widely acknowledged, if not well documented. Battelle recently has undertaken a project, Medpak, to study the consumption, use, and disposal of medical products and packaging by health-care facilities in order to assist health-care product companies to develop products, packages, and process concepts that would reduce the volume and cost of managing medical wastes by hospitals and other medical facilities (13).

The growth in the use of disposable in health-care settings is attributable to a number of converging factors in recent decades. These include:

1. increased concern over infection control;
2. decreased available nursing staff (and a need to provide more expedient treatment and more convenient clinical practices);
3. increased cost of health-care labor (and concern over the time needed to handle and sterilize reusable items); and
4. consideration of disposable as part of the general solid waste stream of the health-care facility (with, in the past, resultant low cost for handling and disposal) (94, 17).

One widely held presumption is that the use of disposable is important from the perspective of infection control. Nosocomial (hospital-acquired) infections are a serious concern in U.S. hospitals, with 2 to 15 percent of all in-patients acquiring them and millions of dollars spent to control them (37).

Yet, infection control studies do not indicate a constant and consistent reduction in nosocomial infections where disposable replace reusable products. Other factors also come into play (see box B). Competing concerns over the cost, and more recently the waste implications, of using large quantities of disposable in health-care facilities are now being raised, particularly for products that do not have a direct effect on infection control and patient care (e.g., disposable telephones).

[4]Types of plastics in products ordered by hospitals include: polyvinyl chloride, polyethylene, polypropylene, polystyrene, and polyurethane (139).

[5]Health risks to employees processing equipment via ethylene oxide sterilization also prompted concerns. Often equipment sterilized by this means, however, cannot be steam sterilized because damage to the equipment would result.

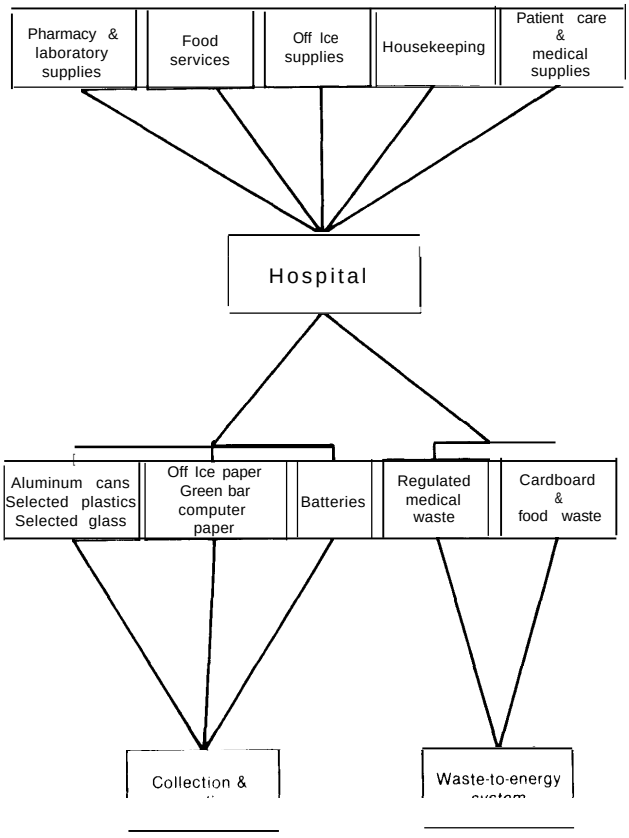
RECYCLING AND SOURCE SEPARATION PRACTICES

In addition to reduction efforts, source separation practices (i.e., segregation of materials as they are discarded based on their characteristics) that target particular materials/wastes for recycling and the most appropriate treatment method can lead to more environmentally sound medical waste management. Source separation before incineration or any other type of treatment has been shown to improve the operation of MSW incinerators, and the same may be true for medical waste treatment as well (1 16). Most health-care facilities segregate infectious and noninfectious waste streams, but separation of other items for recycling may also facilitate management efforts. Yet, any recycling efforts must also consider and address the potential of increased exposure to wastes to health-care workers and waste handlers from such management efforts.

A number of hospitals are adopting recycling programs as part of their waste management programs, although in the past little recycling has occurred by hospitals. A recent reported survey sponsored by the Greater Boston Chamber of Commerce found that hospitals were discarding tons of waste that could be reused or sold and were paying more than other businesses to dispose of noninfectious, commercial solid waste. Hospitals in this metropolitan area, including Massachusetts General Hospital and Beverly Hospital, however, have begun paper recycling programs (9).

Some health-care facilities are planning and developing comprehensive waste management programs, of which recycling is an integral part. For example, Bayfront Medical Center(a518-bed acute-care community hospital) in St. Petersburg, Florida, has proposed a recycle-and-reclaim project in conjunction with its proposed waste-to-energy system (see figure 1). This system represents a comprehensive waste strategy designed to recycle materials as possible, effectively render infectious medical waste noninfectious, reduce the amount of waste going to a landfill, generate energy to power the hospital's laundry, and reduce some of the risks and costs associated with waste management (14).

Figure I—Schematic of One Hospital's Proposed Segregation Categories and Comprehensive Medical Waste Management Approach



SOURCE: Bayfront Medical Center, St. Petersburg, FL.

Cardboard, food, and other general wastes can comprise as much as 85 to 90 percent of a hospital's waste stream, with pathological and infectious wastes comprising the rest (29, 12).[6] Some hospitals are beginning to focus on the nonpatient sources of wastes in their facility and target materials for recycling. For example, corrugated cardboard, computer paper, cans and bottles, and other items (which can contribute metals, particulate, and volatiles to flue gas emissions from incinerators) can be segregated for recycling. Batteries and other noncombustible items that can contribute air emissions of cadmium and lead from incinerators, or if state-of-the-art air pollution control equipment is in place can affect the ash, can also be segregated for more appropriate management efforts.

A Department of Energy study of three MSW incinerators found that presorting not only reduced uncontrolled emissions significantly, but also led to

[6]This estimate is based on hospital survey information reported by Cross (30), see also Cross data cited in (12).

better ash burnout and thereby cut ash volume by half and reduced its toxicity as well. Boiler efficiencies and increased disposal capacities also resulted (heat value increased by 25 percent with presorting) (109).7

The New York City Health & Hospitals Corp., as part of the regional planning effort for medical waste (see ch. 4), has undertaken waste audits of area health-care facilities; when the results are compiled they will set a target goal for reduction and recycling efforts. These types of activities may become more typically associated with efforts to establish treatment facilities.[8] It appears that the emphasis will be on recycling cardboard and other nonpatient wastes in these New York hospitals (71, 67). Recycling of corrugated and high-grade papers may achieve up to 20 percent waste reduction (62, 63). Yet, some items in the entrained regulated medical waste stream may become targets for reduction and recycling efforts as well. For example, based on the preliminary evaluation of the waste audits, disposable linens were a major component of this waste category (62, 63).[9]

An interesting finding is that the red bags and the shipping boxes themselves comprise the largest single component of the regulated waste stream (perhaps as much as 16 percent) (62, 63). Alternative forms of packaging that will reduce the volume and weight of the waste stream, as well as potentially some toxic components, may be considered provided they will ensure safe and adequate handling. For example, some reusable, versus disposable, sharp containers are available (62, 63).

The preliminary results of the New York City medical waste study indicate that the amount of regulated medical waste escaping the MWTA system may be as high as the amount actually captured by it. Further, the amount of nonregulated medical waste entrained in the regulated waste stream maybe about 50 percent of the total captured medical waste (63). Importantly, weight, volume, and cost reductions are predicted to be achievable through better segregation, management, and accounting practices at the department levels of hospitals (51). Education is important to achieve the cooperation necessary to ensure successful changes in such practices.

Improved waste segregation can reduce the amount of regulated medical waste requiring disposal by 30 percent (43). Enlightened management practices can also dramatically affect the volume of waste requiring treatment-and influence the cost associated with managing that waste. For example, the true cost to dispose of medical wastes from different departments can be included in costs charged on a patient basis and become reimbursable under Medicare (see ch. 6). Other management controls that can improve options for waste reduction and recycling include internal controls over unused products and materials, bulk purchasing, and adoption where feasible of reusable products (e.g., food service items) (62, 63).

Beth Israel Hospital (a 1,000-bed major metropolitan hospital) in New York City is one of the frost hospitals in that area to recently institute a recycling program.[10] The initial program involved recycling corrugated cardboard and office paper (including computer printouts and computer tab cards). The program will be extended to include newspapers, magazines, bottles, and cans. The hospital expects to recover approximately 13 tons of computer printout paper and computer cards and 300 tons of corrugated cardboard per year (28).[11]

Beth Israel purchased a baler to improve the ability to market the corrugated cardboard. It was expected to quickly pay for itself, given the anticipated savings in waste disposal costs of over $100,000 a year (based on avoided disposal costs) (28). Colorful collection folders given to workers for their desks, collection bins placed near photocopying machines and related work stations, and posters and flyers explaining the goals and logistics of the recycling program are all part of the educational and

[7]Medical waste incinerators burn a higher Btu value waste than municipal solid waste incinerators (10,000 Btu v. 5,000 Btu). Medical waste itself has been presorted and does not contain the material that one sees in solid waste that lowers Btu value, increases toxicity, etc. (43). Again, the importance of good segregation practices is underscored.

[8]Efforts such as these could significantly reduce the volume of the area's waste stream and will need to be taken into consideration when sizing an incinerator (or alternative treatment method) for the region.

[9]OSHA indicates that its proposed standard prohibits the use of reusable sharps containers, but it may amend this provision if comments on the proposal and evidence indicate that no added occupational hazard is associated with the use of reusable containers (55).

[10]Other hospitals in the New York City area also have adopted recycling programs. These include: Lenox Hill Hospital, Lutheran Medical Center, Metropolitan Hospital Center, and Doctors' Hospital (28).

[11]The participating areas of the Hospital are: management information center, materials management, supply room for pathology, receiving for pathology, central supplies, pharmacy, housekeeping, storeroom.



Photo credit: R. Guttman

Increasingly hospitals are adopting recycling programs to help reduce the volume of waste requiring disposal.

publicity efforts associated with the Beth Israel Recycling Program (67).

The Iroquois Healthcare Consortium, located in northeastern New York, has implemented an aggressive effort to educate its 56 member facilities and assist them in developing and implementing comprehensive recycling programs. The region's success stories include the Albany Medical Center, which currently recycles over 350,000 pounds of cardboard, paper, glass, aluminum cans, and plastic annually. The region has also developed successful programs working closely with local government. In Otsego County, New York, the A.O. Fox Hospital and Mary Imogene Bassett Hospital are two community hospitals that have worked closely with county officials to develop and implement an effective program now being used as a model in the development of the region's recycling program (94).

In several areas of the country, commercial wastes from institutions such as health-care facilities are included in community recycling programs. In these situations, the special nature of the medical waste stream should be taken into account by local planners (e.g., the lower percentage of paper content in hospital wastes than in wastes from some other commercial facilities). Again, health-care facilities will need to ensure proper worker education and training, necessary so that separation practices for recycling will not pose increased hazards to workers.

Recycling efforts by hospitals have been inhibited in some cases by the lack of available markets and in some cases by discrimination against discarded medical materials. For example, in New York State glass intravenous (IV) bottles are not a category of regulated medical wastes, but hospitals report they are unable to successfully market the glass for recycling because it is perceived to be infectious/medical waste (94).

This underscores the need for greater education efforts and better understanding of the nature and actual public health risks posed by the various components of the medical waste stream. In part to address this need, the Iroquois Healthcare Consortium held a meeting sponsored by hospitals at the Albany Medical Center in June 1990 to discuss opportunities and existing programs for recycling certain materials from the medical waste stream (94).

Obviously, some items (e.g., most sharps) in health-care settings are not likely candidates for recycling or reuse, but a surprising volume of materials in health-care settings have reduction, recycling, and reuse potential. For example, a new company (a joint venture of Standard Textile Co. and Marriott Food & Service Management) was recently announced that will offer hospitals recyclable, protective, sterile surgical linen packs. The company claims the specially designed barrier fabric products (e.g., surgical drapes and gowns) will be highly protective and safely recycled at a cost lower than disposable (69).

The importance of product packaging on the total waste stream can also be significant and a focus of waste reduction efforts. Health-care facilities can hold medical product manufacturers accountable for reductions in packaging and for constructing products that use recycled materials and/or that are reusable or recyclable (65).

Some organizations encourage the recovery of medical items that would otherwise be discarded. For example, sometimes more than one disposable kit is opened in order to use just a part of it for a procedure, or items are opened and then not used. Rather than being discarded, sometimes these items are stored, desterilized (if necessary), and then sent overseas for use there. Outmoded medical equipment that can still be used in other countries is also sometimes sent (139, 84). (It should be noted that no governmental guidelines exist currently to ensure the safety of these practices.)

An organization in Texas, the Medical Benevolence Foundation Presbyterian Medical Mission Fund, is one such organization that collects equipment from medical facilities in the United States to send to developing countries where it will be used (139). A network of surgical nurses supporting this type of 'recycling" is being organized in Oakland, California (84). The group, called RACORSE Network (Recycling, Allocation, and Conservation of Operating Room Supplies & Equipment), hopes to facilitate efforts to direct needed medical supplies overseas that would otherwise be discarded here.[12]

[12]Legal implications of this activity and its safety are being reviewed by the group. The goal of RACORSE is to help make the practice safer by establishing recommended protocols (84).

Chapter 3

Non-incineration Treatment Technologies and Trends

Of the still unresolved issues regarding medical waste management, one of the most critical is which technologies and controls are most appropriate for treatment.[1] Clearly, the answer depends on the particular circumstances of the medical waste generator and the host community for the treatment facility. Factors such as the nature (quantity and types) of the medical waste, the availability of permitted landfill space, local air quality conditions, and other demographic and geographic factors (e.g., urban v. rural locations) need to be considered when selecting the most appropriate management strategy. Safety, reliability, and costs of alternative treatment methods and the regulatory certainty associated with their use also affect selection of treatment alternatives. Knowledge of various incineration and non-incineration alternatives can also facilitate adoption of medical waste policies at all levels of government.

While some States and localities actively encourage incineration as a preferred method of treatment, others have enacted moratoriums on incinerators to suspend permitting until further information on the safety of the option is available or new regulations governing it are completed. Thus, incompleteness and uncertainty characterize regulatory activity for medical waste management.

The dilemma now facing New York State facilities, for example, can occur elsewhere depending upon how a State adopts regulations. Facilities there must make management decisions regarding whether to upgrade existing on-site incinerators no later than the fall of 1990 in order to be able to meet New York State's new air quality standards by January 1, 1992. At present many facilities are seeking treatment technologies alternative to incineration; however, to date the State Health Department has not developed and implemented standards for the approval of treatment alternatives. As a result, the State government is limiting the available treatment technologies to the previously approved methods of incineration and autoclaving. This delay in the evaluation and approval of alternative technologies may prevent many New York State facilities from using them, including technology already approved in other States and/or technology which could be more attractive from both financial and environmental perspectives (94).

This chapter, based on available information, addresses the variety of available and emerging non-incineration treatment alternatives, their technical capabilities, and their risks and costs. First, treatment of medical wastes by autoclaving (i.e., a process of steam sterilization), the most frequently employed alternative to incineration, is discussed. Then, a number of other alternative treatments are examined: steam disinfection and compaction; mechanical/chemical disinfection; microwaving; irradiation; and other emerging treatment technologies.[2] Chapter 4 discusses various incineration options, including co-incineration and regional incineration, and pollution control issues, as well as risk and cost implications. A comparison of non-incineration and incineration treatment alternatives is included in chapter 6.

Increasingly, questions are raised about the availability and performance of non-incineration treatment alternatives for medical wastes. While the majority of medical waste is autoclave or incinerated, some medical waste (treated or untreated) is landfilled, including some categories of infectious wastes. The State of Washington found in its survey of medical facilities that some infectious wastes are about as frequently treated by autoclaving as by incineration (139). In addition, other treatment methods, including disposal into the sewer system, are not rare. It should be noted again that most treatment alternatives some form of solid waste disposal, usually either incineration or landfilling, will be necessary.

[1]It should be noted that treatment in this report refers to a process to render wastes noninfectious, unless otherwise indicated, such as treatment to reduce toxicity of wastes, or treatment to render wastes nonrecognizable.

[2]This chapter relies on the OTA contract report, "Medical Waste Treatment Technologies," completed by Robert Spurgin, Spurgin & Associates, March 1990. See also (30) and (73). It should be noted that mention of a specific company or treatment technology does not constitute endorsement of it by OTA. OTA does not endorse any specific application of the various incineration and nonincineration treatment alternatives.

The viability of alternative technologies has increased in recent years due to the increased cost of incineration, the difficulty associated with permitting incinerators, and the perceived desirability of reducing dependence on incinerators given concerns over their emissions. A number of States (e.g., New Jersey, California, Washington) are attempting to encourage adoption of alternative technologies for such reasons. EPA is conducting several research projects to evaluate various waste treatment technologies as required by MWTA (92).

The extent of detail contained in these EPA studies is not known, but the Agency does report that ''most of the treatment technologies are as effective [as incineration] in rendering medical waste noninfectious" (141). In addition to the usually higher capital, maintenance, and operating costs of incineration, EPA cites the public perception problems and uncertain regulatory climate associated with incineration as disadvantages of incineration compared to alternative treatment technologies (141). Landfill availability and other factors, however, will also influence a medical or health-care facility's choice of treatment technology.

Alternative treatment technologies are less capital intensive and have fewer emission concerns than incineration processes. Although it is important to recognize that oftentimes more than one treatment technology may be needed to manage all components of the waste stream (e.g., incineration of pathological wastes that cannot be autoclave). Further, the nature of emissions and efficacy of new treatment technologies must be demonstrated.

AUTOCLAVING

Historically, autoclaving or steam sterilization has been used as a treatment method in laboratory settings to sterilize microbiological laboratory cultures (104).[3] The first commercial steam sterilization process for medical infectious waste was introduced in California in 1978. As incineration requirements were tightening in California, it became clear that insufficient off-site capacity existed to replace closed on-site incinerators, which would not meet the State air emission standards (see ch. 5).

Autoclaving is a process by which wastes are either sterilized or disinfected prior to disposal in a landfill (114) (see figure 2).[4] Autoclaving can be a sterilization process if all microorganisms are exposed to the steam for a sufficient temperature/pressure/time period to assure their destruction. The routine achievement of sterilization can be monitored by placing Bacillus stear other mophilus spores into the center of a load to be autoclave. If the spores survive, then the conditions for sterilization have not been achieved; if the spores are destroyed (i.e., fail to grow in microbiological media after steam sterilization), then the conditions for sterilization have been achieved (given the practical limitations of this routine test).

If the spores have not been destroyed during steam sterilization, then sterilization has not occurred. However, some level of disinfection of the waste would likely have resulted. Unfortunately, the level of disinfection cannot be routinely or practically measured. Sterilization of infectious waste is generally regarded as "overkill" for most waste disposal situations. Disinfection of infectious waste is probably a more reasonable goal for most infectious wastes, though some appropriate and measurable disinfection goal should be established (1 11).

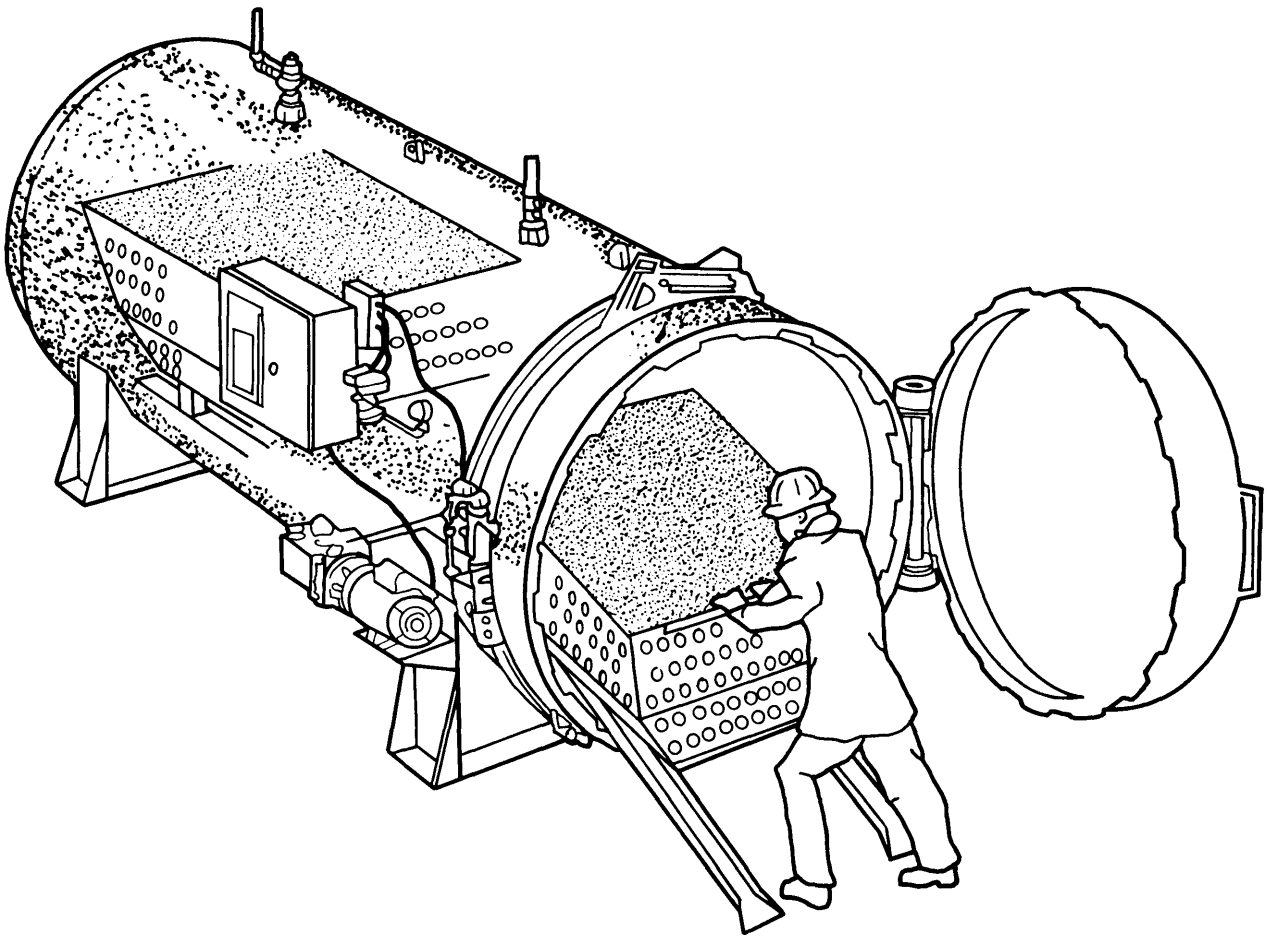
Most steam sterilizers in use for treating infectious wastes are of the high-vacuum type (92). In the autoclaving process, bags of infectious waste are placed in a chamber and steam is introduced for a determined period of time (usually about 15 to 30 minutes) and pressure. The use of pressure helps reduce the required time for disinfection of medical wastes, yet the amount of time required will still vary depending on the type and volume of waste (141). Steam temperatures are usually maintained at 250'F or slightly higher (to disinfect the waste more quickly and allow for shorter cycle times).

Autoclaving parameters, e.g., temperature and residence/cycle time, are determinedby the factors influencing the penetration of steam to the entire

[3]Ethylene oxide and other gas sterilization processes are typically used to sterilize processes for medical equipment, but are also sometimes used to treat wastes. EPA, however, does not recommend ethylene oxide for treating infectious wastes because of its toxicity and given that other treatment options are available (122).

[4]Sterilization is a process that destroys all microorganisms (e.g., pathogens). Disinfection is a process intended to reduce the number of microorganisms or pathogens as low a level as possible, at least below the level at which exposure to a susceptible host could not result in an infectious disease. Actual sterilization is not likely to be maintained once wastes leave the autoclave, as is true of incineration ash residue (see studies cited in 134); thus, disinfection is a more accurate term.

Figure 2—Autoclave



SOURCE: AMSCO, Erie, PA.

load and consequently the extent of pathogen destruction (114, 30) (see figure 3).[5] Generally, complete pathogen destruction should occur if sterilization is the goal of treatment (92; see discussion in 114).

A major advantage of autoclaving is its ability to scale to various on-site and off-site treatment requirements, including the possibility of multiple units that can be located close to the areas where wastes are generated. Most health-care facilities do not use the largest available autoclaves and some companies are beginning to market smaller, tabletop units for use by doctors' offices and other small generators (141). Autoclaving is considered appropriate for treating most regulated medical wastes, except pathological wastes (see below). Commercial spore indicator kits provide easy and reliable quality control capabilities for autoclave systems if sterilization is the goal of treatment (141, 92).[6]

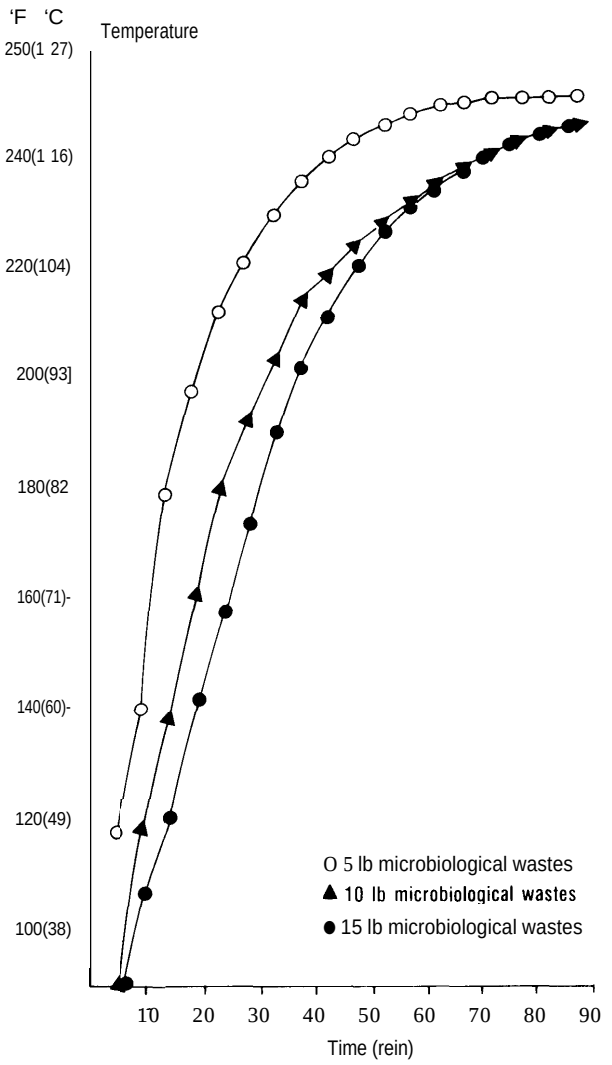
Capacity and Siting Issues

Browning-Ferris Industries (BFI), the largest off-site waste management company for medical wastes, has employed autoclaving since 1976. Other large waste management companies and regional waste management firms use autoclaves as well (104). Indeed, one large waste management firm

[5]See OTA's background paper (1 14) on medical waste for a more complete description of the autoclaving process and operating parameters.

[6]If disinfection is the goal of treatment, spore strip testing would not have a use.

Figure 3—Typical Sterilization Destruction Curve



SOURCE: William Rutala et al., "Decontamination of Microbiological Waste by Steam Sterilization," Applied Environment/ Microbiology, vol. 33, 1982.

reports that it is currently siting more autoclaves than incinerators. Meanwhile, some hospitals continue to use on-site autoclaves for treating their own medical waste. The demand for autoclaving appears to be increasing across the Nation, as the rest of the country begins to experience the shift from heavy reliance on incineration and the increased need for off-site medical waste treatment that emerged in California in the late 1970s.

A major advantage of autoclaving is the capacity a single unit can provide without the spatial requirements associated with incineration systems. The capacity of an autoclave is a function of its size and throughput.[7] For example, an autoclave capable of disinfecting 4,000 pounds per hour of medical waste measures 8 feet in diameter by 24 feet in length, which means it occupies about as much space as a 500-pound-per-hour incinerator (104).

Autoclaving maybe limited in some applications because wastes that are only autoclave are still recognizable-unless they are then shredded or compacted (see below).[8] EPA points out that the ''recognizability' of medical wastes is only an issue in States covered by MWTA and that most States have not found it necessary or practical to adopt such a requirement (141). The potentially high costs of requiring the nonrecognizability of treated wastes have led some to question the wisdom of a requirement to address solely an aesthetic concern.

In the past, landfill refusals of autoclave medical wastes frequently occurred. A variety of reasons account for these refusals, but usually they happened because landfill operators could not easily identify whether waste had been treated and disinfected. Efforts to use bags that change in some visible way in response to autoclaving (e.g., that melt in the autoclaving process or have a strip that changes color) apparently have met with mixed results (104). A nonrecognizability requirement is one solution to this problem, albeit a potentially costly one.

Another solution is for commercial users to have their own private, permitted landfills for disposal. Informal discussions by OTA with a number of hospital officials across the country indicate, however, that few refusals occur if a hospital works closely with landfill operators to explain their waste procedures. The State of Washington reports from its 1989 survey that 86 percent of the hospitals responding to the survey have not had a waste collector or landfill refuse to accept its waste because of its potentially infectious nature (139).

For States under the MWTA program, wastes must be treated and destroyed or rendered nonrecognizable to be exempt from the tracking program. This would necessitate that some form of shredding

[7]The size of the autoclave loading hopper and the cycle time needed for disinfection% however, affect and limit autoclave throughput (63).

[8]Historically, problematic operation has also been a factor leading some hospitals to abandon autoclaving (114). Apparently, recent improvements in the technology have minimized some of these concerns. Proper operation, however, is key to the effective functioning of any treatment technology.

be employed before shipping the autoclave waste off-site; otherwise use of the manifest form would be required to meet the tracking requirements. An option for Congress is to amend MWTA (or related follow-ens) to allow verified autoclaved wastes to be exempt from manifesting. This essentially means modifying the nonrecognizable criteria of the regulatory program.

Suitability for Different Medical Wastes and Associated Risks

Some wastes are not suitable for autoclaving. '' Suitability,' however, is determined by both technical and nontechnical factors. For example, particular pathological wastes are sometimes considered unsuitable for autoclaving (principally for aesthetic reasons, i.e., they will not be rendered nonrecognizable).[9] In any case, approximately 90 percent of the regulated medical wastes generated are suitable for autoclaving (104). Autoclaving is considered particularly appropriate for microbiological wastes (e.g., laboratory cultures). In contrast, autoclaves are not suitable for cytotoxic and other toxic chemical wastes because of the hazardous nature of these wastes. In addition, contaminated animal bedding is not autoclave.

To the extent that autoclaving is used for only a portion of medical wastes, then it can be used as a supplement, more than a substitute for incinerating medical wastes. Yet, if wastes are segregated for treatment based on their chemical and physical characteristics, it is likely that a smaller fraction of waste will require incineration. Additional segregation of the items requiring incineration (or other treatment) is not usually necessary since these wastes are generated and/or managed separately .10

Documented health impacts from autoclaving do not exist. It is of critical importance that certain wastes, due to their either hazardous or pathological nature, not be autoclave. For example, autoclaving hazardous materials such as antineoplastic agents, radioisotopes, solvents, or other toxic wastes could lead to chemicals being volatilized by the steam and could result in possible worker exposure between process cycles. If autoclaves are of a gravity-displacement type, steam "escapes" through an outlet vent, most of which is condensed and drained into the sanitary sewer.[11]

Potentially, if the waste itself contains trace elements of formalin or other carcinogenic compounds, workers could be exposed to the aerosolized compounds if they come in contact with the venting steam (104). Once again, the importance of separating waste materials for diversion to the most appropriate treatment method is evident (e.g., in this case, hazardous materials to a hazardous waste treatment option). Further study of emissions from autoclaves is warranted based on the fact that infectious wastes may contain significant levels of cytotoxic compounds or low level radioactive wastes and concerns that the presence of such substances could lead to emission problems.

A noticeable odor in the steam discharge, described by one knowledgeable observer as ''much like styrofoam cups tossed in a campfire," is not known to be harmful (104). Odor-controlling tablets that can be added to each autoclave load are available.[12] The potential for problems with landfill leachate associated with autoclave waste is not known, but in general the survival of viruses in solid waste leachate does not seem to occur.[13]

Costs and Volume Reduction Issues

Autoclave units are generally not as costly as on-site or off-site incineration alternatives. An autoclave unit will cost between $30,000 and $100,000 installed (depending on the size of the unit), with annual operating costs at about $0.05 to 0.07 per pound plus labor, with an expected equip-

[9]The phrase "pathological wastes" throughout this report refers to wastes of human origin (e.g., tissues, organs, body parts). Pathogens and pathogenetic wastes should be distinguished from pathological wastes (of human origin). Pathogens and pathogenetic wastes are components of the microbiological waste type (see ch. 1).

[10]For example, in most hospitals all tissue samples are transferred to pathology for analysis before disposal and can be collected separately there for incineration.

[11]These discharges to the sanitary sewer system should be innocuous in their impact although an industrial waste water discharge permit may be required by the local sewage district authority (see ch. 5).

[12]OTA did not determine Whether these tablets mask the odor or actually change the chemistry, or whether their effect makes a difference from a human health perspective.

[13]See literature review and discussion by Turnberg (110), from which the author concludes that research has not established a relationship between landfill leachate and solid waste and disease, and that obtaining evidence of such a relationship is difficult and further research is necessary. Also see refs. 138, 103, 44.

ment lifetime of 10 to 15 years. Landfill costs must also be taken into account, but overall this treatment option appears less expensive than incineration and management of its ash residue (if it has to be sent to a hazardous waste landfill). The State of California concluded from its preliminary cost data that autoclaving and other non-incineration alternatives may be more economical for some small medical facilities than retrofitting existing incinerators to meet their newly proposed air emission control measure (108).

If autoclave waste is not subsequently compacted or shredded, there is no significant volume reduction. Yet, given that medical waste represents such a small percentage of the solid waste stream, it does not pose a significant contribution to landfill capacity problems experienced in some areas of the country (and landfill waste cost is usually charged on a weight rather than a volume basis). For example, California reports that if all on-site incinerators are abandoned for alternative treatment methods, the medical waste requiring landfilling would only represent 0.03 percent of the waste currently handled at MSW landfills in the State (108).

AUTOCLAVING AND COMPACTION

High-vacuum steam sterilization combined with the compaction of treated waste began in California in 1978 and is increasingly being used in the Northeast and Mid-Atlantic areas of the country. As of May 1990, over 100 units are in operation. This treatment process combines an autoclave with a stationary compaction unit intended to handle the regulated medical waste as well as the solid waste from a health-care facility (see figure 4). The system is designed to be used as an on-site treatment alternative (104, 48, 30).[14]

The high-vacuum autoclave removes air, which acts as a steam displacement barrier, and thereby shortens the time for the steam to achieve the necessary operating temperature (approximately 284 °F) and permeate the entire waste load. This means that exposure to the waste is faster and the cycle time is reduced, which is estimated to be between 40 and 50 minutes from loading to loading (104).

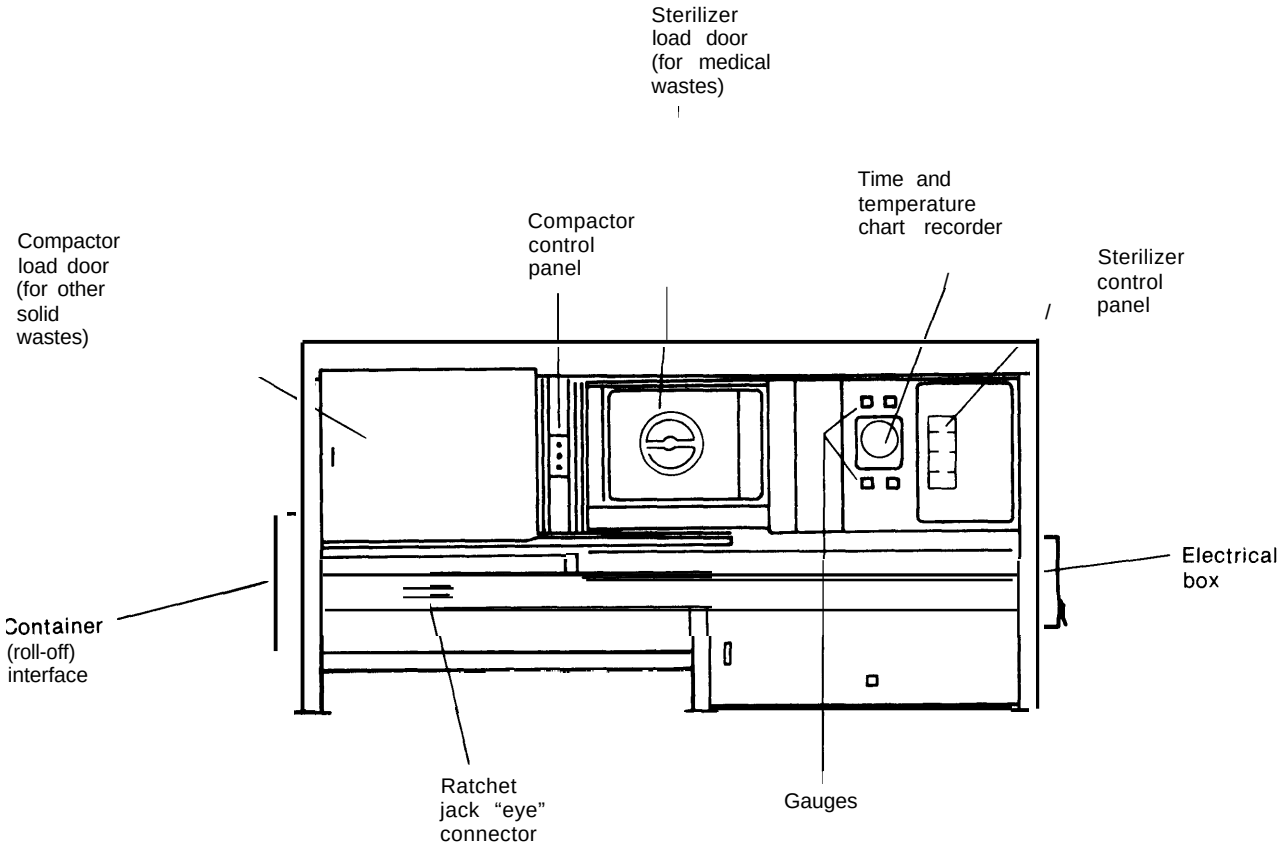
The disinfected waste is then hydraulically fed into the solid waste hopper, where it is compacted with general refuse from the facility and automatically fed into the refuse bin or trailer for hauling to a solid waste facility. Operators are not exposed to the treated medical wastes, reducing the risk of exposure to sharps, fluids, or other waste items. As with most autoclaves, no separate fuel source is usually needed since live steam from existing boilers in the facility's physical plant can usually power the system (104). The compaction process achieves a 60 percent reduction of volume of the waste, and higher levels of up to 80 can be achieved if corrugated cardboard and other recyclable materials are separated from the waste to be compacted and landfilled.

The system is increasingly being adopted on the east coast, even in States covered by MWTA (where the autoclaved/compacted waste must be tracked). In New York State, however, the two restrictions associated with compacted, autoclave waste have limited the application and acceptance of this alternative. First, the New York State Department of Health is requiring that the sharps treated in autoclave/compaction units, such as the San-i-pak units, must be in compaction-resistant containers to prevent spillage and/or exposure to sharps when the compacted waste is placed in the landfill. Second, the ''recognizability' of the compacted waste has resulted in refusal by many local landfills to accept the waste (94). As noted above, however, in other areas of the country such refusals appear less difficult to overcome with explanation and demonstration of the process to landfill operators.

The capital costs are approximately $115,000 to $130,000 for equipment suitable for a 400 bed hospital, with estimates of $35,000 to $60,000 for site preparation (including utilities, slab, drainage, etc.) (48, 94). Operating costs, according to the sole manufacturer, San-i-pak, range from $0.03 per pound when the solid waste disposal costs are $300 per pull (haul) to $0.10 per pound when pull costs run as high as $1,600. Fuel costs are stated to be $0.003 per pound of steam used (47). The operating cost estimate includes this steam and electricity cost, as well as repairs and maintenance, the capitalized cost of the equipment, labor, and bags (48). The systems have an expected lifetime of 15 years (similar to that of most incinerators). The operating

[14]Four sizes of the autoclave and compaction unit are available which will accommodate 1,3,7, or 16 autoclave bags, measuring approximately 38x44 inches each, in a given cycle. Some limited attempts have been made for a commercial off-site use of the technology; such use, however, does not appear as practical as the on-site application for which the unit was designed (104).

Figure 4—Autoclave and Compaction Unit



SOURCE: San-i-pak Pacific, Inc., Tracy, CA.

cost includes hauling costs for infectious and general wastes, and specially hauled wastes, i.e., chemotherapeutic, radioactive, and pathological wastes (estimated to be less than 1 percent of a facility's total waste).

MECHANICAL/CHEMICAL DISINFECTION

Chemical agents such as chlorine have been used as disinfectants for medical products for some time, although the application to large volumes of infectious wastes generated by hospitals and laboratories is more recent (104). This type of technology, which has been available since the mid- 1980s, is referred to as "mechanical/chemical' because of mechanical maceration and chemical disinfection (a result of forcing a reaction that occurs to volatilize waste material and expose all of the pathogens to a chemical disinfectant in a controlled environment); the residue is discharged to the sewer system.[15]

Chemical disinfection processes, according to EPA, are most appropriate for liquid wastes, although they can be used to treat solid wastes (122). The appropriateness of the process for pathological wastes is not clear (92). A number of factors should be considered regarding the effective use of chemical disinfection, including: the types and biology of microorganisms in the wastes; degree of contamination; type of disinfectant used (usually sodium hypochlorite, commonly known as chlorine bleach) and its concentration and quantity; the contact time; mixing requirements; etc. (122). As with other treatment alternatives, efficacy of the method needs to be demonstrated through the development of a biological testing program and monitoring on a periodic basis using appropriate indicators in order for the system to be adopted and used on a routine

[15]This type of system is also sometimes referred to as "hydropulping" (see 30).

basis. Test results reported to date find the process, using chlorine bleach, to be an effective disinfectant for medical wastes contaminated with vegetable bacteria and viruses, but less effective against spore-formin g bacteria (92).[16] No standard protocol has been developed to evaluate the efficacy of the system and to assist in developing standard operating procedures for it (92).

Maceration of the medical waste, involving high-speed hammermill blades and/or shredders, requires use of copious amounts of water. To keep the unit from overheating as well as to disinfect the waste, water is introduced along with the disinfectant (usually chlorine-based) during the maceration phase. The simultaneous volatilization and introduction of the disinfectant is designed to render the wastes noninfectious. The introduction of water creates a liquid waste, which is discharged to the sewer.[17] This means an industrial waste water discharge permit from the local sewage district may be required.

According to Research Triangle Institute's (RTI) contractor report to EPA, "Once the proper operating parameters such as the flow rates for water and chlorine solutions are established the device is simple to operate and requires little training" (92). The nonrecognizable nature of the byproduct of the mechanical/chemical treatment process and its ability to treat liquid medical waste before discharging it to the sewer system are important factors accounting for the favorable market response to this treatment alternative. The waste treated by the process is rendered nonrecognizable by the shredding and pulverizing phases, which are primarily for treatment efficiency but act to destroy the waste as well (104).18 This means that the waste meets the nonrecognizability criteria of MWTA and would not have to be tracked under its manifest system.

Increased concern over the practice of discharging untreated liquids (e.g., blood and other body fluids) into the sewer system also makes the mechanical/chemical process with its discharge of treated liquids an attractive alternative. Yet, it is not clear that this system would reduce any risks that might exist as a result of direct discharges in a facility of blood and body fluids into the sewer system (see ch. 5). Further, the sewage system contains countless human pathogens from the vast quantity of human body waste. Liquid medical waste comprises only a minor fraction of this overall waste flow. Microbiologically, there is little difference between blood waste and fecal/urine waste (except that fecal wastes would be expected to have a far greater number of human pathogens) (11 1).

The process is designed for on-site use with possible applications to a variety of medical and health-care settings (see figure 5). The frost company to manufacture such a system (Medical SafeTec., Inc.) currently offers three machines, one for larger applications and the other two for laboratory settings. A similar system was designed by a company for application in the funeral industry. This company also has a clinical machine for sharps and plans to offer over 200 separate machines for a wide variety of health-care applications. While the one company is offering a system that would require a large facility to purchase one unit, the other company is marketing smaller machines for use throughout the hospital (104).

States such as California and New Jersey, which are open to innovative technology for medical waste generally, are a responsive market for this alternative. Some large generators converted to this system, rather than replacing or retrofitting existing incinerators (104). Currently, about 40 of the smaller units are in use, primarily for sharps management. These systems can treat pathological waste (e.g., formalin-fixed tissue samples) and most other medical wastes. [19] The system is powered electrically with standard electrical requirements. Sewer connection is mandatory, and, as noted, a local discharge permit may be necessary. Concern has been raised over the level of metals, organics, and other contaminants that may be in the sewage discharge (5).

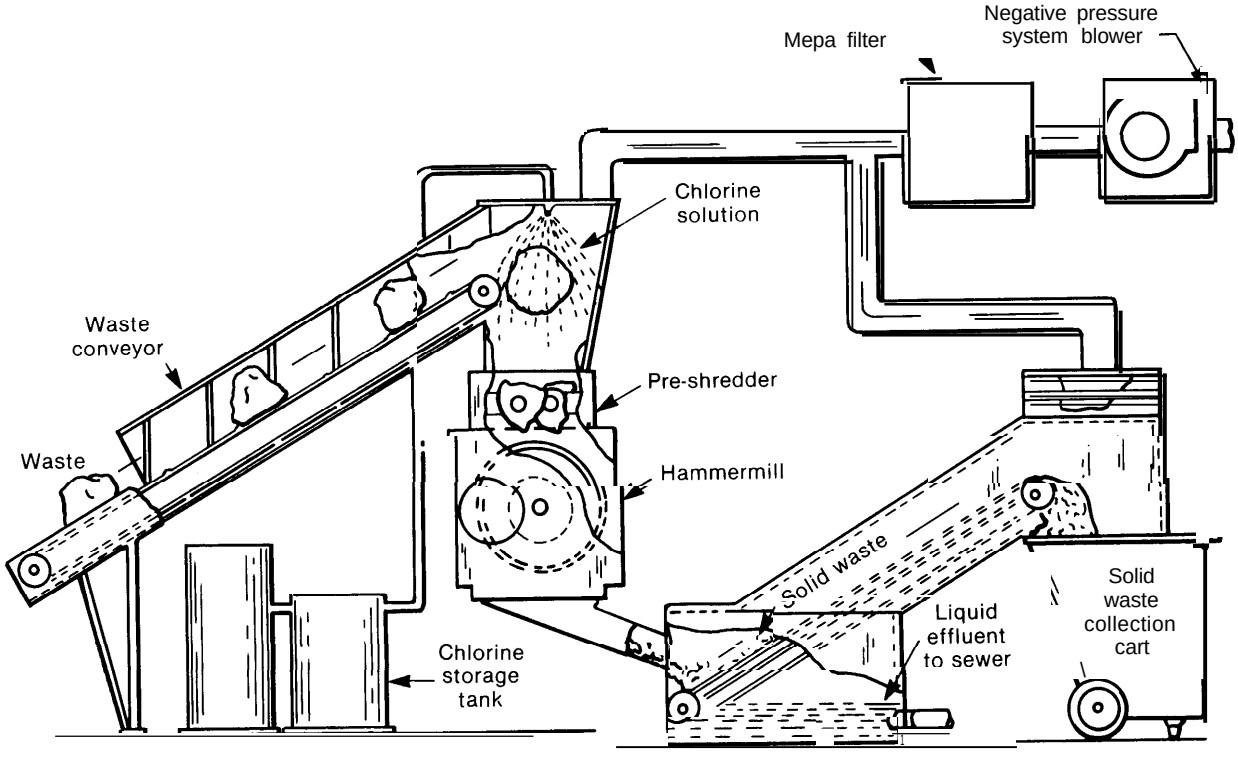
[16] Hazard and occupational risk from the handling, storage, and use of chlorine have been suggested as a potential disadvantage of this technology (94).

[17] Reportedly, systems that shred and disinfect medical wastes that will not require use of copious amounts of water or a sewer discharge are being developed (63). One such process will combine conventional shredding technology with the use of special red bags. These red bags have a small seam that envelops a few grams of formulated powder (a water-activated disinfectant). Treated material is "only slightly moist, no longer recognizable. . disinfected and volume-reduced'' (78).

[18] A preshredding system, which is part of the large hammermill, breaks up the waste materials before the hammermill pulverizes them.

[19] The EPA states, however, that these units are not normally recommended for pathological waste types (141).

Figure 5-Mechanical/Chemical Disinfection Unit



SOURCE: Medical SafeTec, Inc., Indianapolis, IN.

The percentage of dissolved solids in the discharge into the sewer is high (up to 10,000 ppm v. 300 ppm for residential users), but the manufacturer states that changes necessary to reduce the level to that of other points of discharges are now feasible (104). Even so, the liquid effluent contains high concentrations of substances, e.g., chlorine, that may require pretreatment before being discharged to the municipal sewer system. It would appear that local permit levels for sewage discharges would have to be met.[20]

There are no air quality regulations that are relevant. Although it is not clear there is a need for any air regulations, given that no known air emissions problems have been encountered, little has been reported about the nature of the emissions. There is some concern over the potential for producing volatile chemicals and/or microbes during the shredding process, although the system is designed to control emissions and force air through a series of prefilters and a chlorine-resistant falter before discharging it to the atmosphere (141, 5). The use of chlorine and the potential impact on sewage discharges is also raised as a concern with the chemical disinfection process. Further study of these issues is needed, possibly as part of EPA's current research on alternative treatment methods.

The mechanical nature of the equipment, with so many moving parts, means it could require a high level of maintenance. This also means there is more potential occupational exposure. The manufacturers note that no injuries involving equipment repair or maintenance have been reported.[21] As with an autoclave unit, the space needed for a mechanical/chemical unit is not large and the capacity is then mainly a factor of the throughput rate for the unit. The smaller units require an area approximately 10

[20]RTI (92) reports that waste treatment effluent from the Medical SafeTec unit has been tested according to the specifications published under the Clean Water Act for pollutant analysis (40 CFR, Part 136).

[21]Yet, as with other treatment alternatives, it is not clear how frequently accidents are reported (given concerns over potential impacts on insurance premiums, etc.).

feet by 9 feet and the units with additional capacity would require areas of 11 feet by 10 feet.

Capital costs are approximately between $40,000 and $50,000 (equipment and installation) for the smaller units and approximately $350,000 for the larger sized unit. Operating costs are reported to be $0.06 per pound of waste per hour of treatment (104).

MICROWAVE

The application of microwave technology to disinfect medical waste was introduced in Europe several years ago. The technology is from West Germany and just recently is being marketed in the United States (34). The units can be on-site or mobile facilities. The first on-site installation was in North Carolina in March 1990. A second commercial system began operation shortly after this in California as a supplemental technology to an existing regional incinerator (104, 34).

Powered by electricity, the unit shreds the waste in a controlled environment; the waste then enters the chamber for exposure to the microwaves (see figure 6). The disinfection process takes place through microwave heating, which occurs inside the waste material (unlike other thermal treatment methods which heat wastes externally) and wetting and shredding the waste to facilitate heating and steam penetration of the waste. The material is discharged to a storage bin for ultimate disposal.

Computerized controls, as with most other treatment technologies, are used to ensure the minimum parameters for disinfection and proper function of the equipment. Fire and temperature conditions necessary for waste sterilization are the same as those for autoclaving (92). Studies conducted in Germany by the Institute of Hygiene, University of Gottingen concluded that the process treated material to a lower level of bacteria content than ordinary household wastes (as reported by ref. 35). Performance tests at a unit operating in the United States, using a Bacillus subtilis microbiological spore test indicator, found the wastes to be treated under conditions to render it sterilized (35). Research Triangle Institute reports that although the method is essentially a steam sterilization method, it is necessary to confirm that conditions required for steam sterilization exist in the microwave process (92).



Photo credit: Vetco Sanitec Corp., Combustion Engineering, Stamford, CT

Microwave units can be installed on-site or be used as mobile units. Mobile units could facilitate collection of regulated medical wastes from home health-care settings, doctor offices, and other small generators of medical wastes. This type of mobile microwave unit has been used in Berlin, West Germany for several years.

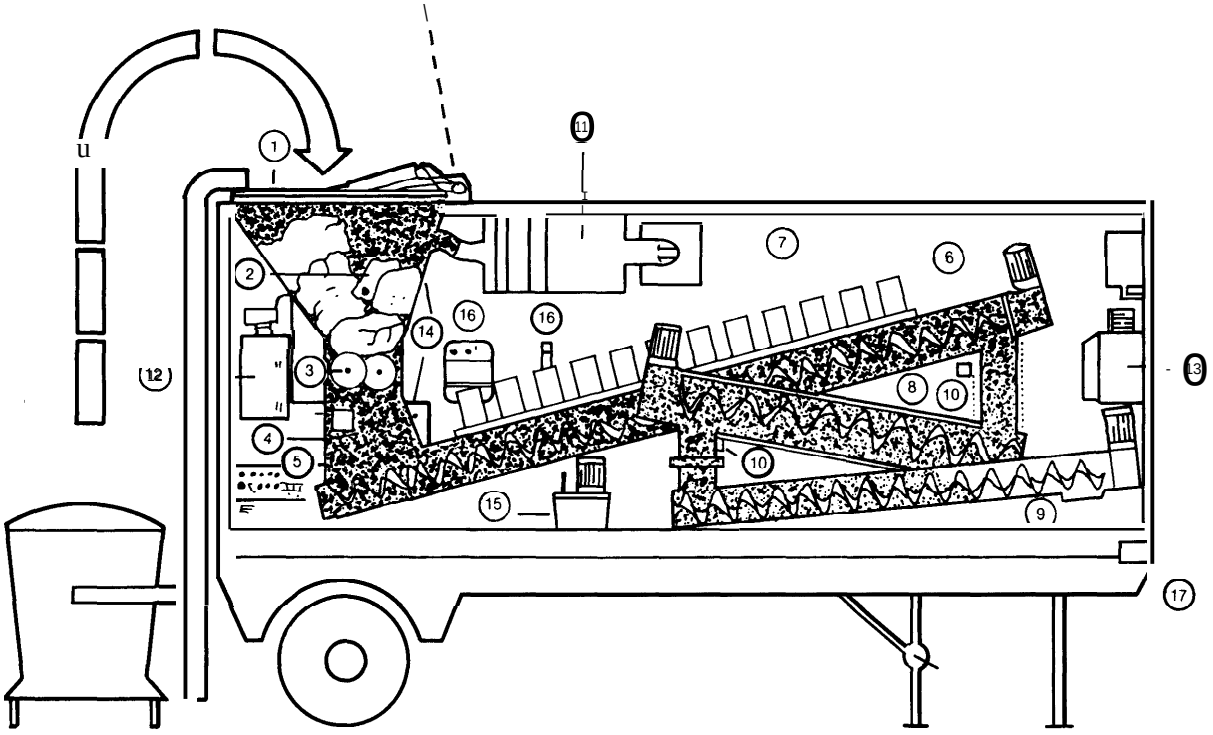
As with autoclaving, approximately 90 percent of medical wastes can be treated by this method (it is not recommended for pathological wastes). The use of electricity averages about $0.02 per pound. Energy use is reportedly lower than that of an incinerator (35). The shredding process results in a volume reduction of 80 percent prior to disposal. Treated wastes are suitable for disposal in a solid waste landfill. Given that the process is used in Europe with no reported emission problems, its acceptance is anticipated in the United States (35, 104).

The microwave system is designed to be operated by unskilled labor. All adjustments in wastes levels and time are preprogrammed into the system (92). Operating and maintenance costs are reported to be approximately $0.10 or $0.07 per hour, depending on whether the system is operated 8 hours or 10 hours a day, respectively. Capital costs are about $500,000 for a unit (35). It appears that health risks associated with the unit would primarily be associated with the maintenance of the shredder component of the system. Potential operator exposure to volatized chemicals during loading or cleaning/ maintenance should be examined, however.

IRRADIATION

A common practice is to treat medical products with radiation for sterilization purposes (104). The high cost of cobalt used in the process and high operating costs have discouraged commercial ventures from using the technology for medical waste management. In February 1990, however, the first

Figure 6—Mobile Microwave Medical Waste Disinfection Unit



Process scheme of a mobile microwave-disinfection unit

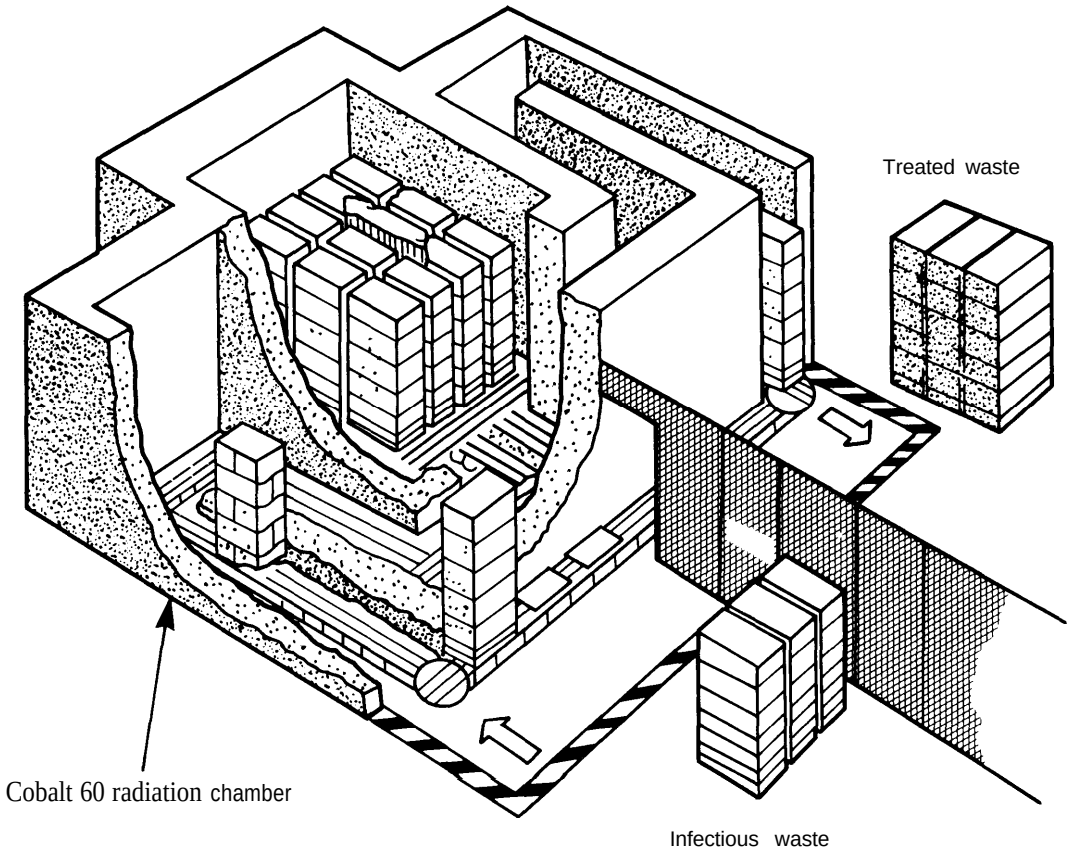
1. Feeding hopper
2. Feeding crank
3. Shredder
4. Connecting hopper with inspection window
5. Level sensors
6. Main conveyor auger
7. Microwave generators
8. Temperature holding section
9. Discharge conveyor auger
10. Temperature sensors
11. Filter system, 2-stage
12. Water tank with pump and spraying connection
13. Steam generator
14. Steam connection
15. Hydraulic aggregate
16. Room heater
17. Container

SOURCE: Vetco Sanitec Corp., Combustion Engineering, Stamford, CT.

commercial medical waste irradiation facility was opened in Arkansas, and additional facilities are planned in California and New Jersey. Questions have been raised about the actual process of radiating the material and achieving adequate disinfection (104) (see figure 7). Garoma radiation sterilizes infectious waste by penetrating the waste and inactivating microbial contaminants. The ionizing radiation hydrolyzes the water molecules within the micro organisms and these intermediate hydrolysis products interact with the gamma radiation and biological compounds, are broken down and are rendered noninfectious. The company pursuing this treatment technology emphasizes that the waste will not be disposed of as solid waste. Rather, it is shredded, rendering it nonrecognizable, and is shipped to a cement kiln where it is burned as fuel (104).[22] Eventually, one such operator of a system

[22]It should be noted that concerns have also been raised about the practice of burning wastes in cement kilns, which typically are not subject to air emission standards (other than the new source performance standard (NSPS) for particulate matter emissions). The assumption is that these kilns operate at such high temperatures that wastes used as fuels are destroyed without producing harmful emissions. This is an unsettled regulatory issue. It is true, however, that any cement kiln burning MSW would be subject to air emissions standards for MSW incinerators as proposed by EPA in December 1989.

Figure 7—irradiation Unit



SOURCE: Technology Process, Inc.

plans to separate the plastic waste and sell the treated plastic residues for recycling (92, 101).

The process is highly predictable, according to RTI's analysis (92). Verification of the conditions for disinfection involves using Bacillus pumilis as a test indicator organism. According to RTI, no studies specifically addressing the efficacy of gamma irradiation of medical waste for disinfection (92). In addition, film is placed between every few boxes to quantify the amount of radiation each box receives (104).

Again, this treatment method is not recommended by EPA for pathological wastes. The capacity of these units is a factor of the throughput rate. The units are an off-site alternative and can manage all types of waste, except pathological wastes. The approximate operating cost could be $0.15 per pound. Potential risks of this alternative treatment technology are primarily associated with the possibility of radiation exposure to workers.[23]

OTHER POTENTIAL TREATMENT TECHNOLOGIES

Other technologies with potential application to medical waste management are in a conceptual or experimental stage in their development. Several are mentioned here to illustrate the variety of attempts to develop treatment alternatives for medical wastes.

One technology that has recently been announced as available and capable of thermally destroying biomedical wastes uses an electric molten glass furnace. At least with other waste types, the wastes are fed into the furnace and are subjected to intense heat (2,300 'F) and air and water vapor. The result

[23]Workers operating these systems would have to be trained according to the 10 CFR "S~nd~ds for Protection Against Radiation" regulations. Operators would need to be highly trained to ensure the efficient and safe operation of the process.

is the vaporization or oxidation of some wastes and a inert stable glass residue (87).

Electrohydraulic disinfection and pulse-power technology were created as disinfection systems for contaminated liquids. Their uses are not widespread, although the concept of applying the technology to medical waste disinfection has been suggested. It appears that the perceived high cost of this technology is a major reason it has not yet been developed. The process involves the use of pulsed plasma of electrical discharges in water, using ultraviolet radiation, hydrogen, hydroxil, ozone and shock waves to act as disinfectants. One application of pulse power technology does not require the use of radioisotopes (104).

Future application of plasma torch technology to medical wastes (and other hazardous wastes) has been suggested (42, 39, 31). A "pyroxidize," a small pyrolysis on-site laboratory waste disposal unit, is being developed (92). Another recently announced potential treatment technology is an electrocatalytic oxidation system (38).

Adaptations of existing technologies have been suggested, for example, a sterilization/dry grinding method (30). This system would combine an autoclave system with dry grinding/shredding in a hammermill to achieve both volume reduction and nonrecognizability of the wastes. Projected costs for this hypothetical alternative treatment are $0.08 per pound (30). It is not clear whether the increased maintenance cost usually associated with shredders is taken into consideration in these calculations. One reason frequently given for the limited application to date of shredders is that they require a high level of maintenance. Thermal inactivation or dry heat sterilization, reportedly sometimes used for both solid and liquid medical wastes, also could possibly be used in conjunction with a shredder or compactor (although it is not considered as efficient as steam disinfection) (73).

SUMMARY

Several non-incineration alternative treatment technologies for medical wastes are commercially available, others are at a conceptual or developmental stage. Autoclaves, autoclave/compaction units, mechanical/chemical units, and most recently microwaving and irradiation treatment alternatives are in use in medical facilities across the Nation. Most of these units are on-site treatment alternatives and most appear less costly than incineration. Many of the alternatives will achieve significant volume reduction (of 60 percent or more) of the medical waste and all can render wastes nonrecognizable (if a compactor or shredder is added). Weight reduction may or may not occur, particularly if water is added during the treatment process. In fact, some of these treatment alternatives can add to the weight of waste, given their use of water. These alternatives appear to have fewer emissions concerns (although these warrant further study) than incinerators. Most of these alternatives do not appear appropriate for pathological wastes.

Health risks associated with these technologies have not been thoroughly investigated. Further examination of potential health risks is warranted (particularly for the newest applications, e.g., microwave and irradiation). When any waste treatment alternative is considered, any new or additional employee exposures that could result from utilizing the new method should be identified and evaluated.

Before adopting a medical waste management strategy, medical waste generators must first know the applicable regulatory requirements and then assess the capabilities, costs, and associated health and environmental risks of various treatment technologies as applied to their facility in order to adopt the most appropriate technology for their needs. It is likely that the emergence of these non-incineration alternative treatment methods will reduce but not eliminate the current level of dependence on incineration for medical wastes. Many of these alternatives can be viewed as supplementing the use of incineration for treating medical wastes. Pathological wastes are the one type of regulated medical wastes for which incineration remains the preferred treatment alternative (122, 92).

It appears most prudent for any regulatory program for medical waste to avoid directly or indirectly encouraging a particular type or application of treatment technologies. Rather, flexibility for the generators to meet their management needs and comply with regulatory requirements will allow for adoption of the most appropriate treatment options and help ensure safe management of medical wastes.

Government agencies, particularly EPA, could facilitate the evaluation and adoption of new treatment alternatives by developing a program for demonstrating the efficacy of a treatment

method. A general protocol for the certification of approval of any type of waste treatment technology (e.g., hazardous, solid, medical) could be established with adjustments made for developing appropriate testing programs (e.g., biological testing of medical treatment methods).

Interim approval status might be given while test protocols and results are developed and/or pilot projects, perhaps at veterans' hospitals or other government facilities could be used. Monitoring new facilities on aperiodic basis, perhaps with some supporting funding, could facilitate developing appropriate operating parameters and specifications. A program similar to the Superfund Innovative Technology Evaluation Program has been suggested as a model for a program evaluating new medical waste technologies (31, 124).

Such efforts could help ensure that government regulatory activity does not create barriers for evaluation and adoption of new technologies. An important task for State and Federal regulators then is to rid the current regulatory system of inconsistencies and ambiguities and enable the "market" to move ahead with optimum management solutions.

Chapter 4

Incineration Treatment Issues and Trends

Incineration of medical wastes remains a prevalent treatment method in the United States.[1] It is also the treatment technology most often used for medical wastes in other Western countries (57, 58). The advantages of incinerating medical wastes, are those associated with the incineration of any type of waste: significant volume reduction (by about 90 percent), assured destruction, sterilization, weight reduction, and the ability to manage most types of wastes with little processing before treatment.[2] The disadvantages include potential pollution risks associated with incineration processes and increased costs associated with controlling pollution emissions (114, 116).[3]

In some European countries it appears that regional off-site incineration facilities have been encouraged to optimize the economical application of advanced pollution control technologies (57). In the United States, incineration continues to occur on-site in smaller units, most of which have few or no pollution controls. As some States adopt more stringent air standards for medical waste incinerators, 90 percent or more of these existing units can be expected to retire when these new standards go into effect within the next several years (e.g., New York State, California) (12). New on-site as well as off-site units can be designed to meet stringent emission control standards, and some older, on-site facilities can be retrofitted with air emission controls (if sufficient space and the economics make this practical). Retrofitting can include modifying the incinerator, adding or changing pollution control devices, or both.

While new regional facilities are being established and other new on-site facilities are operating in the United States, it is also likely that incineration will be supplemented by other treatment technologies. Nearly 80 percent of the hospitals in California use alternatives to on-site incineration (49). Several interrelated factors account for the likely decreased dependence on incineration:

1. the increased cost of incineration due to increased equipment needs to meet new emission standards and permit requirements;
2. siting and permitting difficulties associated with locating new incineration facilities;
3. regulatory uncertainty associated with incineration requirements at the local, State, and national levels of government; and
4. the increasing availability of nonincineration alternatives for treatment of medical wastes.

In fact, increasing concern over incineration in general and particularly for medical waste has resulted, in some States, in indirect regulatory encouragement for developing alternative treatment technologies.

More specifically, the regulatory emphasis by States has been on operation requirements for increasing temperature, residence times, and combustion efficiency to foster destruction of toxic compounds in the combustion process in order to preclude their release to the atmosphere. The required temperatures are tending to be set increasingly higher than necessary to destroy pathogens. According to EPA, the incinerator conditions needed to destroy gas stream pathogens emitted from the medical wastes are a function of temperature, residence time, and good mixing to preclude 'pockets' of gases (which do not reach the required temperature). Based on limited available data, at typical residence times, temperatures (for the secondary chamber) necessary for pathogen destruction are 1,600 'F or more. Most existing regulations usually require temperatures of 1,800 or 2,000 'F, higher than the temperature probably needed for pathogen destruction, but considered necessary to control other emissions such as volatile organics (e.g., chemotherapy agents) (41).

Incineration technology continues to evolve, and more sophisticated pollution control equipment is becoming available. Another source of concern,

[1]Most of these incinerators are of the controlled-air type (see below and 114). This type of incinerator is popular for medical wastes because it typically is more fuel-efficient and has lower particulate emissions than other smaller, modular combustion systems and its solid hearth can vapor-combust liquid wastes and ensure that needles are rendered noninfectious.

[2]Although separation of noncombustibles and items with problematic constituents improves maintenance and possibly air emissions.

[3]Once other treatment methods (e.g., autoclaving) are more thoroughly studied, however, increased costs to ensure their environmental safety may also occur. Nonetheless, most nonincineration alternatives are less capital-intensive than incineration.

however, is the potentially hazardous nature of incinerator ash. As air pollution control equipment becomes increasingly effective in removing particulate matter and toxic substances from flue gases, the potential toxicity of fly ash collected from the equipment is likely to increase.[4] Effective destruction of toxic substances during combustion (i.e., of some organic chemicals, as opposed to metals) would minimize the presence of those substances in flue gases; this would reduce the amount requiring removal by pollution control equipment and thereby reduce subsequent concentrations in fly ash residues collected from the equipment. The toxic materials captured in the fly ash are usually disposed of in a landfill.[5] Limited data available on the constituent nature of medical waste incinerator ash indicates it can contain a number of hazardous substances (e.g., heavy metals; and dioxins and furans in fly ash) (as reported in 114) (54a).

The presence of a toxic substance in ash does not necessarily mean it presents an environmental hazard. This depends, for example, on its volubility and how it is managed (e.g., whether conditions will allow leaching or gaseous emissions that lead to inhalation or ingestion of the substance) (116). In this light, the nature and management of ash from medical waste incinerators requires careful consideration. To date, little information is available about its nature and potential hazards.[6] EPA, as part of its NSPS test program, will be collecting and analyzing both bottom ash and fly ash samples for dioxins and heavy metals.

This chapter reviews: 1) the regulatory trends driving the market and development of incineration options; 2) capacity, cost, and risk issues associated with incineration; 3) current trends in the selection of air pollution control systems; and 4) prospects for co-firing medical waste with other waste types and for regional incineration.

REGULATORY TRENDS AND MEDICAL WASTE INCINERATION

Currently, trends in medical waste management are primarily being driven by State regulation, particularly of air emissions, of medical waste incinerators. At the Federal level, the Clean Air Act, which is being re-authorized, is a source of concern to the medical waste incineration industry.[7] Less attention has been paid to the regulation of incinerator ash from medical waste incinerators. Increased State and/or Federal regulation of ash disposal could increase insurance (due to potential RCRA and "Superfund" liabilities if it is considered hazardous) and other operating costs for managing the ash (presumably off-site at a specially controlled landfill).[8]

The Waste Combustion Equipment Institute (WCEI) testified before the Senate Committee on the Environment and Public Works that the proposed Clean Air bill would inappropriately apply standards for large MSW incinerators to incinerators of different types and for different wastes, such as medical wastes (45). At the same time, EPA is in the process of formulating its new source performance standards (NSPS) for medical waste incinerators under its existing authority in the Clean Air Act. They are expected to be proposed in 1992. Some NSPS and other types of Federal standards have been established for MSW.[9] The Agency initially considered

[4]Fly ash is comprised of light particles that are either carried off the grate by turbulence, or that condense and form in the flue gas in the boiler system. Bottom ash is the residue from combustion (ash) that accumulates on or falls through the grate of the incinerator. Most volatile metals (e.g., lead, mercury, cadmium) are concentrated in fly as& whereas other types of less volatile metals (e.g., aluminum, chromium, iron) are concentrated in bottom ash (1 16).

[5]Currently, if the State regulates an ash testing program, the material should be tested, and if it is hazardous it should be sent to a hazardous waste facility. See OTA (1 16) for a discussion of the current unresolved state of ash regulation at the national level.

[6]Although Wrote Management, Inc. indicates that its testing of medical waste incinerator ash det ermined that the quality of the ash is similar to MSW incinerator ash (43). See OTA (1 16) for a discussion of the nature and management of MSW incinerator ash. Lauber and Drum (66) report that EP toxicity tests at one facility with advanced pollution control equipment have tested the ash and found it to be nonhazardous.

[7]USCA 7401 et seq.

[8]See OTA, 1989 (116) for a more detailed discussion of MSW incinerator ash and possible management and regulatory scenarios. presumably, medical waste incinerator ash, which has been found to be more hazardous than MSW ash in some cases, would be regulated in a similar way as MSW incinerator ash (54a).

[9]Currently, at the Federal level, NSPS for particulate matter and opacity emissions are set for MSW incinerators. MSW incinerators also must meet the mercury standard which is regulated as a hazardous air pollutant and the national ambient air quality standards [set for such pollutants as nitrogen oxides and carbon monoxide (1 16)]. The revised NSPS for MSW incinerators, proposed by EPA on Dec. 20, 1989, would cover acid gases, dioxins/furans, nitrogen oxides, carbon monoxide, and metal emissions and revises the particulate matter and opacity standards to more stringent levels (41). In addition, emission guidelines for existing MSW incinerators were also proposed in the Federal Register on Dec. 20, 1989.

including medical waste incinerators in their proposed air emission standards for all incinerators burning more than 50 percent MSW on November 30, 1989. Those proposed standards would have applied to most medical waste incinerators and required a 90 percent reduction in air emissions through emissions limits, operating standards, and some source separation and recycling requirements. Apparently, at this time EPA is considering a lower size cutoff for the MSW NSPS standard, which would essentially exclude medical waste incinerating. Instead, a specific NSPS for medical waste incinerators would be adopted (41).

At the State level, over half the States have changed their requirements for medical waste management within the last 2 years (107). Most of this regulatory activity focuses on setting stricter air emission standards for medical waste incinerators. Currently, the standard-setting process for air emissions from medical waste incinerators in California is attracting considerable attention (see box C). The California Air Resources Board (CARB) is proposing regulations for medical waste incinerators that would require reducing emissions of dioxins by 99 percent or to 10 nanograms per kilogram. There is no cadmium requirement, but local air districts are recommended to evaluate the need for such standards on a case-by-case basis.

Originally, the proposal required the use of a dry scrubber/baghouse combination for air pollution control equipment, as the best available control technology (BACT), to achieve the desired removal rates. Any other technology that could document the necessary reductions in dioxins could also be

Box California and Its Dioxin Control Measure: A Case Study of One State's Approach to Regulation of Air Toxics and Medical Waste Incinerators

On July 12, 1990, a proposed "air toxic control measure" (ATCM) requiring a 99 percent reduction in dioxins or control to a level no greater than 10 rig/kg of medical waste burned was adopted by the State of California.[1] It is the culmination of an effort begun when the California Air Resources Board (CARB) identified dioxins as toxic air contaminants in July 1986.[2] CARB is required to evaluate the need for and the appropriate degree of control for a compound that is identified as a toxic air contaminant (106, 108).

Through a formal risk management process, medical waste incinerators were found to have the greatest individual risk potential of all dioxins sources the State identified. This, combined with the facts that most of the incinerators are uncontrolled and located in residential areas and that emission test results from eight test facilities found that they were also sources of other pollutants (e.g., cadmium, benzene, polycyclic aromatic hydrocarbons, lead, mercury, nitrogen oxides, sulfur dioxide, particulate matter, and hydrochloric acid), led CARB to give medical waste incinerators the highest priority for the dioxin ATCM (106, 108).

CARB identified 146 facilities that incinerate medical wastes in the State of California. Of these, 137 are on-site facilities incinerating 28 percent of the total amount of medical waste incinerated, and 9 are off-site, regional facilities incinerating the remaining 72 percent of the medical waste incinerated. The on-site incinerators are typically located at a medical facility and mainly incinerate general solid waste (70 to 95 percent by weight of the total amount of waste incinerated), similar to MSW, with infectious and pathological waste (5 to 30 percent by weight of the waste incinerated). The incinerator may generate steam and hot water, but the only current air emission regulation is a particulate matter emission standard set by the local air pollution control district (49, 106, 108).

Regional incinerators in California are located to serve many medical facilities and incinerate only pathological and infectious wastes. These facilities have particulate matter and HCl emissions regulated by the local air pollution control districts and the Department of Health Services (49, 106, 108). These regional facilities manage nearly 75 percent of the infectious waste incinerated in the State (8,700 tons per year of the 12,105 tons per year of infectious

[1]After the adoption of the CARB control measure, local air pollution control districts have 120 days to propose and 6 months to adopt a regulation at least as stringent as that adopted by CARB (106, 108).

[2]According to California law, a toxic air contaminant is "an air pollutant which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health' (California Health and Safety Code Section 39655).

Continued on next page

wastes incinerated). The amount medical waste currently incinerated represents about 0.05 percent of the total general waste produced in California annually (49, 106, 108).

CARB emissions testing of eight California medical waste incinerators served as the basis for developing the ATCM. The emission rate for dioxins from these eight facilities ranged from 0.0003 to 14,140 rig/kg of waste burned. A multipathway risk assessment (which considered exposure to inhalation, dirt ingestion, dermal absorption, and mother's milk) estimated that the risk for dioxin is 1 to 246 chances of developing cancer per million, with the lower end of the range reflecting controlled facilities. Based on these findings, CARB identified control equipment that could reduce dioxin emissions by 99 percent or to 10 rig/kg and determined that waste disposal alternatives to incineration are available (106, 108). The proposed control measure is expected to reduce the maximum individual risk by 90 to 99 percent, to 1 to 3 chances of developing cancer per million (49, 106, 108).

The proposed ATCM for dioxin of 99 percent reduction of dioxins or reduction to a level no greater than 10 rig/kg of waste burned is considered to be BACT (the best available control technology). Although CARB first identified a dry scrubber and baghouse air pollution control system as the most effective in reducing dioxin emissions, it later tested and reported that a well-designed incinerator equipped with a Venturi wet scrubber achieved the 99 percent reduction (i.e., the proposed emission limit for dioxins). The proposed control measure also includes requirements to ensure combustion efficiency to minimize dioxin formation, These include a minimum temperature of 1,4000 °F in the primary chamber of a multiple chamber unit and a minimum temperature of 1,800°F in the secondary chamber of a multiple chamber unit or the primary chamber of a single chamber unit, with a one second gas residence time (106, 108).

In addition, a maximum temperature for flue gas at the outlet of the air pollution control equipment is specified as 300°F (unless an alternative temperature achieves equal or greater control). The control measure also specifies requirements regarding continuous record keeping for the operation of equipment and maintenance; reporting violations, malfunctions, or upset conditions; annual source testing; operator training; and mandatory air district permits (106, 108).

The proposed measure became effective July 1991, and the compliance timetable is for installation of BACT 15 months after the local air district's adoption or to cease operation 6 months after the district's adoption. The dioxin control measure is expected to increase waste treatment costs by approximately $0.10 to $0.35 per pound over current incinerator costs. In addition to the reduction in the risk to 1 to 3 chances of developing cancer per million, the control measure is expected to produce other net environmental benefits (106, 108).

considered for permitting (e.g., wet scrubber systerns). This provision was modified, however, to State performance standards (e.g., a 99 percent reduction requirement) without regard to the specific technology necessary to meet them. The proposed final standard became effective on July 12, 1990. Reported test results from one facility show a 99 percent reduction and 10 rig/kg achievable with a well-operated incinerator equipped with a high-efficiency Venturi (wet) scrubber (107).

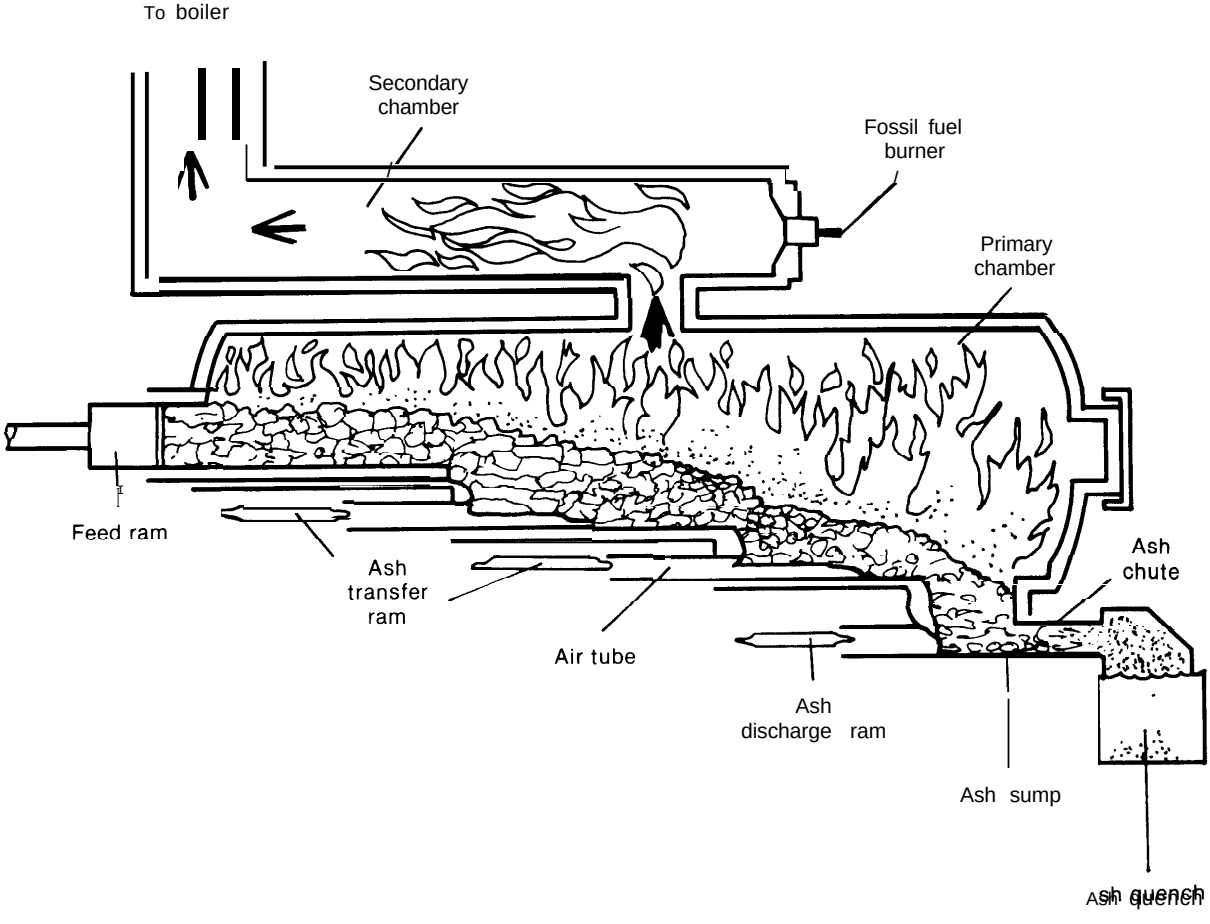
Given the large number of medical waste incinerators (on-site and off-site) operating in the country, separate regulation taking into account the special characteristics of these incinerators and the nature of the wastes they burn may be most appropriate.[10] MSW incinerators tend to be large, mass-burn incinerators (i.e., waste is burned as-it is received, not processed or sorted), which are typically one-chamber combustion systems operating under conditions of excess air. Most medical wastes are burned in excess air or controlled air incinerators (sometimes referred to as starved air incinerators), which burn waste in two or more chambers under conditions of either excess oxygen or a deficiency of air, respectively (1 14, 45, 30, 40) (see figure 8).[11]

As with MSW incineration, a trend may be emerging for medical waste incineration to recover energy and include front-end waste separation and

[10]The exact number of medical waste incinerators operatin, in the country is not known with certainty. The State of California, with 10 percent of the U.S. population, reports 146 medical waste incinerators (49).

[11]EPA finds, based on information gathered in MWTA States, that approximately 40 percent of total number of incinerators are ones operating under excess air conditions and 35 percent are starved air units. These excess air incinerators are probably small incinerators used for pathological wastes and have limited or no air pollution control equipment. They are probably not required to meet most air quality standards due to their size unless they are in a State (e.g., New York, California) tbat has recently adopted new air quality standards (141).

Figure 8-Controlled Air Incinerator



SOURCE: U.S. Environmental Protection Agency, Industrial Incinerators, EPA-450/3-80-013 (Washington, DC: May 1980).

recycling efforts. Such efforts, along with designing the incinerator to account for the nature of the wastes, affect incinerator performance. A recent study of the performance of hospital incinerators concluded that while performance-related problems and emission exceedance problems can be caused by poor equipment design, they are "more likely caused by the incineration of wastes different, in type or mixture, than originally anticipated" for the system (81). Accurate waste analysis and designing the incinerator to accommodate that waste feed will help avoid waste-related operational problems.

In any case, the absence of controls at the Federal level and the variation of controls at the State level create a highly uncertain and complicated regulatory climate for those who make, sell, and use medical waste incinerators. Siting and permitting medical waste incinerators in most areas of the country have become as problematic as siting any type of waste facility. Public resistance to siting some medical waste facilities focuses on potentially hazardous air emissions (e.g., dioxins, furans, HCl, cadmium and lead emissions) and the disposal of potentially hazardous ash residue (e.g., cadmium and lead content). Pollution control equipment and engineering solutions are being applied to control these emission and residue problems (e.g., scrubber equipment to control particulate and HC1 emissions and higher combustion temperatures and retention times in the secondary chamber of incinerators of one to two seconds at 1,800'F to control organics) as well as efforts to separate materials for recycling, including such items as batteries, which contribute to the level of metals in the ash.

CAPACITY, COSTS, AND RISKS

Capacity

The advent of stricter environmental controls for incinerators and the prospect of the resulting closure of many existing facilities has fueled concerns over whether adequate incineration capacity for medical wastes is available nationally. This discussion will focus on capacity issues, which are driving trends in technology and permitting, and will indirectly (qualitatively) identify the general level to which a capacity problem exists in this country.

It is extremely difficult to determine existing incineration capacity (or demand/need for capacity) on a national basis given the differences between on-site and off-site incinerator capacity parameters and the fact that the amount of medical waste (including nonhospital sources) requiring treatment is not definitively known (104). It does appear, however, that the demand for capacity has outpaced its availability in some regions of the country, especially where new, more stringent State requirements lead to the closure of existing facilities and newer facilities are not readily available (given the lengthy permitting process and the persistent siting problems).

The capacity problem is most likely to arise when on-site incinerators shut down because they can no longer meet regulations, when management practices (e.g., universal precautions widely applied) increase the amount of waste requiring incineration, or when increasing numbers of nonhospital generators enter the market. If a large number of on-site incinerators cease operation, for whatever reasons, in the same geographic region, a ''capacity crunch' can occur (104). This capacity deficit can result in either accelerated permitting or increased export (transfer) to other regions. In California, new regional incinerators are being permitted, which will provide surplus capacity for medical waste, no longer burned on-site (49). In New York State, increased out-of-State shipment is anticipated at least in the short-term after new regulations take effect (94).

Increasingly, older, on-site units are being replaced either with larger, on-site units that can be regional (accepting medical wastes from nearby clinics and nursing homes) and/or co-incinerate the facility's medical and solid wastes, or with off-site regional incineration. The customer base for regional incinerators continues to grow. Substantial growth in this industry is projected.[12] Interestingly, although total on-site and off-site capacity may be adequate to meet disposal needs, the regional markets determine the fluctuations in available capacity in a given area. That is, the varied generation rates (in part related to regulatory trends and shifts in management practices), the reluctance of major regional incineration and autoclaving operating companies to make capacity available to competitors when the need arises, and regional regulatory trends create an unstable level of treatment capacity (104).

The Southeast (centered in and around South Carolina), lower Midwest (centered in and around Oklahoma), and the Ohio Valley area now appear to have excess capacity for medical waste. Indeed, these areas have been magnets for the waste from other parts of the country where capacity has become saturated. Wastes from locations on both coasts have been transported great distances to facilities in these areas.

The uncertain outcome of the pending changes in the Clean Air Act has slowed the pace of permit applications in a number of States. In the Northeast, constraints on capacity have been driven by such factors as permit difficulties (e.g., the (now expired) moratorium on incineration activity in Pennsylvania). In other areas, there may be permit activity (e.g., Texas, Illinois), but there is a lag between the time when additional incineration and/or alternative treatment capacity will be available in those markets and the immediate capacity needs (104). This can necessitate exporting medical waste out of the area for treatment, at least until new treatment capacity is available. In some areas, a "capacity crunch" is being met by arrangements with local MSW incinerators to accept medical wastes (68; see below). The State of California, when adopting new air emission standards for medical waste incinerators, examined the potential for a capacity shortfall. They concluded

[12] The same is true for the entire medical waste management industry. According to one study, the currently estimated $750 million medical waste industry will expand to $1.5 billion by 1991 and grow to nearly to $5 billion by 1994 (cited in 75). Other studies project revenues to be even higher, reaching $10.7 billion by 1991, with expenditures estimated to grow from $970 million to $2.9 billion by 1991 (cited in 74).

that upgraded or new incinerators, or other treatment alternatives, could be permitted within the timeframe before existing facilities would be required to shut down. Further, the relatively low volume of medical waste incinerated could be landfilled at existing facilities with little impact on their capacity according to CAB.

Changes in regulation of a waste stream can result in short-term shortfalls of permitted treatment capacity (e.g., the shortages of permitted MSW landfill capacity experienced in some areas of the country as States adopt more stringent landfill regulations, leading to closure of many existing facilities). It appears that such temporary shortfalls of permitted capacity can occur for medical wastes. Yet, if adoption of new regulations is coordinated with careful planning and expedient permitting, such shortfalls may be averted.

costs

The variable nature of the equipment design, size, and add-on pollution control equipment make it impractical to identify the typical cost of treating medical waste by incineration (104, 54).[13] Incineration costs can vary by more than 500 percent, and OTA's contractors independently identified wide cost ranges from $0.07 per pound to over $0.50 per pound (104, 54). The California Air Resources Board estimates that uncontrolled incineration costs are about $0.15 per pound and controlled incineration costs about $0.50 per pound (108). It is generally believed that incineration is a more costly alternative than most nonincineration treatment alternatives; some estimates find autoclaving to be 30 percent of the cost of incineration (104).

CARB also calculated the estimated cost to retrofit existing facilities to meet its proposed standards to be an increase of $0.16 per pound of waste burned. If on-site incinerators are shut down and off-site incineration is used, costs are estimated to increase by $0.35 per pound. If steam sterilization is used, on-site, a $0.10 per pound cost is estimated, and if incinerators are shut down and off-site steam sterilization is used, a cost of $0.17 per pound is expected (108).

Risks

Relative health risks associated with the combustion of medical wastes continue to be debated as data remains limited. A thorough examination of health and environmental risks posed by different pollutants is beyond the scope of this effort; these risks are addressed elsewhere (116, 66, 12, 108). The intention here is to identify those pollutants of primary concern in medical waste incineration because of their potential human health and environmental impacts.

These pollutants include dioxins and furans (some of which are thought to be carcinogens), pathogens (entities with infection potential), metals (e.g., cadmium, a neurotoxic chemical and thought to be a probable human carcinogen), acid gases (e.g., hydrogen chloride (HC1), nitrogen oxides, and sulfur dioxides), which can cause acute effects such as eye and respiratory irritation, can contribute to acid rain, and may enhance the toxic effects of heavy metals), and particulate emissions (which can absorb heavy metals and organics and 1odge in human lungs, and serve as irritants possibly responsible for chronic health effects). Their presence in either air emissions or ash residue is a concern.[14]

A large data base for dioxins and furans and their potential carcinogenicity makes them a particular source of concern. It is presumed by regulators that controlling emissions of these organics will control emissions of other organics (PAHs), cadmium, and perhaps particulate matter and HC1.[15] Emissions of these organic compounds from medical waste incinerators have been noted (see table 6 and figures 9, 10, and 11). Barton et al., in a study for the EPA and CARB, hypothesize that dioxin and furan formation can be minimized by controlling particle and trace organic emission levels within the combustion zone, minimizing the time particles are held at temperatures that maximize dioxins and furan formation and maximizing the destruction of precursors (both

[13] EPA, as part of its NSPS program for medical waste incinerators, is evaluating the capital and operating costs of various air pollution control devices and incinerators; the preliminary results are expected in late 1990.

[14] See OTA, 1989 (116) for a discussion of risks associated with MSW incinerator air emissions and ash residues, which may be similar to those associated with some forms of medical waste incineration.

[15] In dry scrubber systems (i.e., acid gas removal plus particulate removal), high removal of particulate matter generally means high removal of heavy metals (except possibly mercury) and moderate to high control of dioxins/furans (and other semi-volatile organics). It appears that particulate matter control is the key to controlling the pollutants noted here, because they are converted to a solid (particulate) form to facilitate their removal from the gas (20).

Table 6-Emissions of Dioxins and Cadmium From Medical Waste Incinerators in California

Percent of total waste incinerated v. percent of statewide dioxins emissions in California:	Percent statewide waste burned [a] (%)	Percent dioxins emitted (%)
119 Onsite incinerators		
Controlled units:		
1. Multiple chamber . . .	21.4	1.3
2. Excess-air	0.07	0.03
Uncontrolled units:		
1. Multiple chamber . . .	25.3	21.0
2. Excess-air [c]	9.9	36.3
Subtotal	56.7	58.6
9 Off-site incinerators		
Controlled units:		
1. Multiple chamber . . .	31.1	2.5
Uncontrolled units:		
1. Excess-air	10.3	38.9
Subtotal	43.4	41.4
Total	100.0	100.0
Percent of total waste incinerated v. percent of statewide cadmium emissions in California:	**Percent statewide waste burned [a] (%)**	**Percent cadmium emitted (%)**
119 Onsite Incinerators		
Controlled units:		
1. Multiple chamber . . .	21.4	15.7
2. Excess-air	0.07	0.1
Uncontrolled units:		
1. Multiple chamber . . .	25.3	32.2
2. Excess-air [c]	9.9	13.8
Subtotal	56.7	61.8
9 Off-site incinerators		
Controlled units:		
1. Multiple chamber . . .	31.1	23.4
Uncontrolled units:		
1. Excess-air	10.3	14.9
Subtotal	43.4	38.3
Total	100.0	100.0

[a]From table X-3.
[b]From table XII-8.
[c]Includes types not specified.
'From table XII-1 O.

SOURCE: State of California Air Resources Board, *Technical* Support Document to Proposed *Dioxins* and Cadmium Control Measure *for Medical* Waste *Incinerators,* prepared by Toxic Air Contaminant Control Branch, Stationary Source Division, California Air Resources Board (Sacramento, CA: May 23, 1990).

vapor and particle bound) within the incinerator (12). They also note that to control dioxins from the flue gas with low-temperature fine particle control merely transfers the dioxins from the air to the ash (12).[16] Yet, metals will not be controlled by these measures; only add-on pollution control equipment or front-end source separation will reduce emissions of metals (41).

As part of its standard-setting process, California undertook what to date is probably the most comprehensive health risk assessment of medical waste incineration. CARB worked closely with the California Department of Health Services to develop a multipathway health risk assessment model to assess the potential acute, chronic and cancer health effects from exposure to pollutants emitted from medical waste incinerators, MSW incinerators, fossil fuel combustion, and hazardous waste incinerators. For dioxins the multiple pathways used to estimate potential risks are: inhalation, dermal absorption, soil ingestion, and mother's milk for the frost year of an infant's life (108). Other routes, such as produce (leafy vegetable) ingestion, can increase the risk relative to inhalation, but were not feasible to consider in this effort. Further studies to supplement the California studies could address this and other exposure routes.

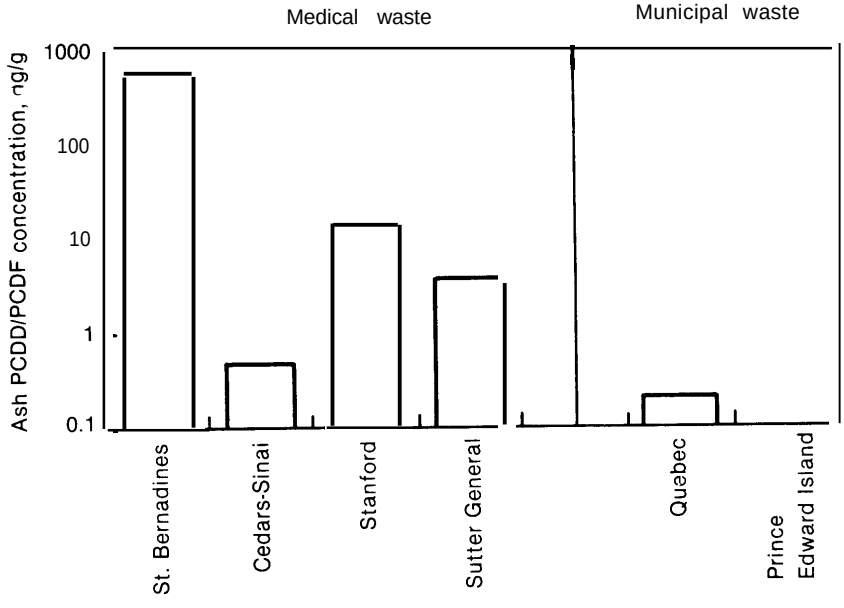
The results of the California risk assessment estimate for dioxins that the risk factor ranges from 1 to 246 in a million of developing cancer for continuous daily exposure for 70 years to an airborne concentration of one picogram per cubic meter of total dioxins. For cadmium, the estimate is that the risk factor ranges from less than 1 to 15 in a million for continuous daily exposure for 70 years to an ambient air concentration of one nanogram per cubic meter (108).

CARB also reported results for potential chronic noncancer effects from exposure to pollutants emitted from the eight hospitals it tested and reported as well on the significance of emissions with the potential to cause chronic health effects. The most significant noncancer effects might come from iron, manganese, and lead. Five facilities were identified as having the potential to cause acute effects in exposed individuals from HCl emissions (108). Yet, the use of the risk assessment and its findings have been problematic in California, and further work needs to be completed in this area.

Beyond disputes over the actual health risks posed by incineration, it appears that effective, available technology will be able to reduce risks to whatever

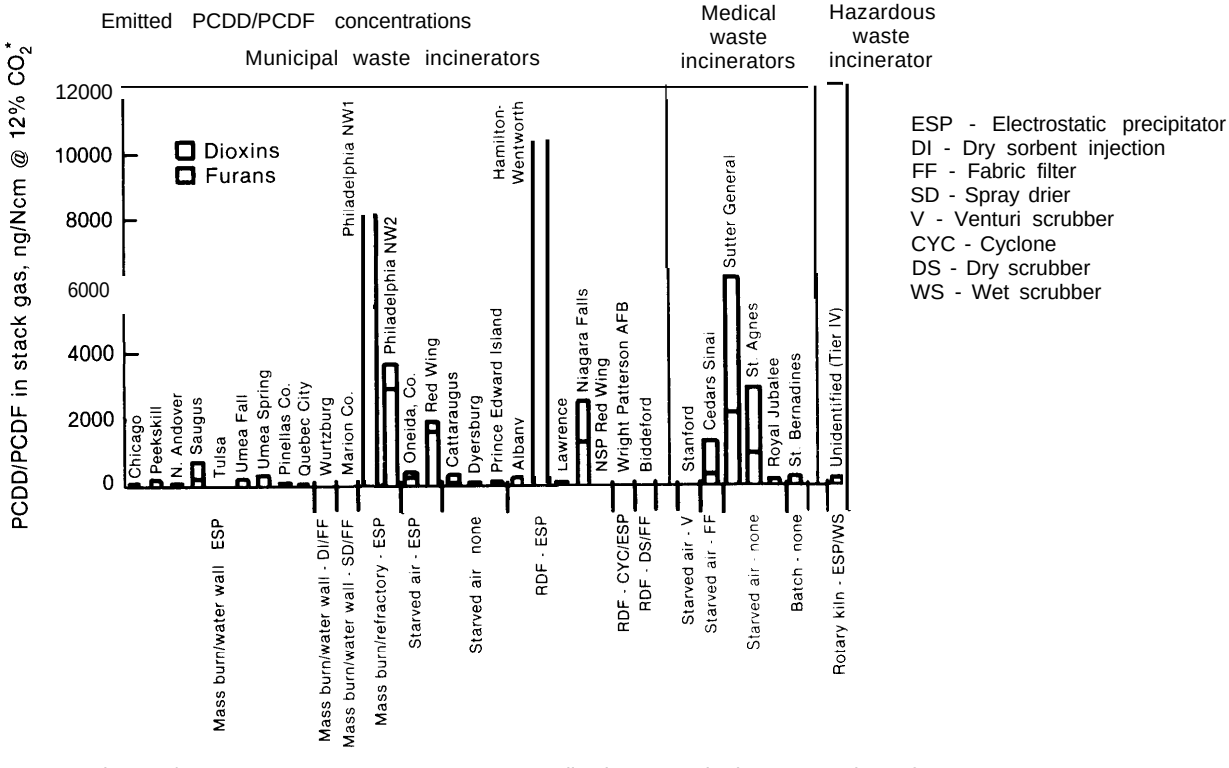
[16]The attachment @on&@ of dioxins/furans t. solids, i.e., the ash, is such that their removal by leaching in a landfill is not considered significant. Thus, concentrating the dioxins/furans in residue allows for their control by landfilling (20).

Figure 9-Comparison of PCDD/PCDF Concentration in Medical and Municipal Wastes



SOURCE: R. Barton, G. Hassel, W. Lanier, and W. Seeker, State of the Art Assessment of Medical Waste Thermal Treatment, EPA Contract 68-03-3365 and ARB Contract A832-155 (Irvine, CA: Energy& Environmental Research Corp., 1989).

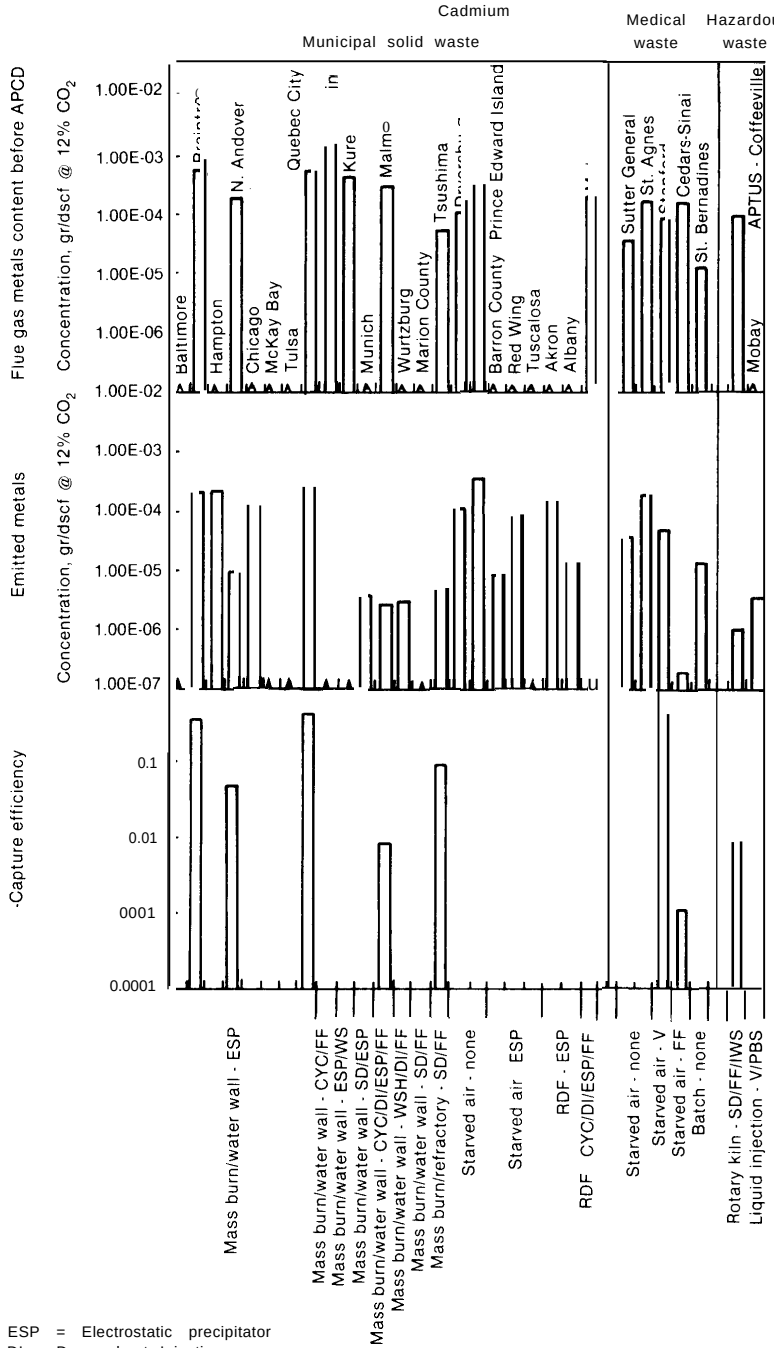
Figure 10—Comparison of PCDD/PCDF Emissions From a Variety of Incinerators



*Note that ng/Ncm represents measurements normalized to standard concentration of 12% CO_2

SOURCE: R. Barton, G. Hassel, W. Lanier, and W. Seeker, State of the Art Assessment of Medical Waste Thermal Treatment, EPA Contract 68-03-3365 and ARB ContractA832-155 (Irvine, CA: Energy& Environmental Research Corp., 1989).

Figure n-Comparisons of Cadmium Emissions From a Variety of Incinerators



ESP = Electrostatic precipitator
DI = Dry sorbent Injection
FF = Fabric filter
SD = Spray drier
V = Venturi scrubber
CYC = Cyclone
DS = Dry scrubber
WS = Wet scrubber
IWS = Ionizing wet scrubber
WSH = Water spray humidifier
PBS = Packed bed scrubber

A = Data not available
D = Metal below detection limit

dscf . dry standard cubic foot; 1 gr/dscf = 2.290 g/Ncm

SOURCE: R. Barton, G. Hassel, W. Lanier, and W. Seeker, State of the Art Assessment of Medical Waste Thermal Treatment, EPA Contract 68-03-365 and ARB Contract A832-155 (Irvine, CA: Energy& Environmental Research Corp., 1989).

levels are defined by standards.[17] CARB, for example, reports that tests demonstrate high efficiency Venturi wet scrubber systems, as well as dry scrubber systems, at well-designed and operated incinerators can reduce risks to acceptable levels, defined by their standards to one to three chances in a million (49, 108). It should be noted though that the heterogeneous nature of the medical waste stream makes it nearly impossible to conclude with certainty what the emission levels of certain substances will be in any given unit. For example, two hospitals with similar incineration systems can have highly different emission test results largely due to the differences in their waste streams and charging methods (104).

TRENDS IN AIR POLLUTION CONTROL SYSTEMS

Until a few years ago when the first major study of emissions from hospital incinerators was completed and some localities set more stringent air emission standards, air pollution equipment associated with these incinerators was minimal (126). Today, some form of scrubbing system is considered a standard part of many new incineration systems, although most medical waste incinerators remain uncontrolled and pollution control equipment is not necessarily a standard part of medical waste incineration systems (41). Pollution control devices currently in use on medical waste incinerators include wet or dry acid gas scrubbers (to remove/neutralize acid gases, etc.), baghouses (fabric falters) or electrostatic precipitators (to remove airborne particulate matter), hybrid dry/wet scrubbers, and afterburners (sometimes used on excess air combustors to reduce toxic organic gases).

A fairly common list of toxic compounds and criteria pollutants to be controlled has evolved through the development of regulations and the permitting process. These substances are: particulate, hydrogen chloride, sulfur dioxide, carbon monoxide, nitrogen oxides, dioxins, furans, mercury, arsenic, cadmium, chromium, nickel, zinc, and lead (104) (see table 7).

The selection of air pollution control systems involves choosing between a wet or a dry scrubber system. A scrubber is an emission control device that adds alkaline reagents to react with and neutralize acid gases, with the resultant products collected for management of residue. For a dry scrubber this is usually done through the use of a baghouse (fabric falter) to trap solid particles (dust), while for a wet scrubber byproducts are discharged as a slurry, possibly requiring treatment before discharge to the sewer. In the future, depending on the type of scrubber used and the sewage discharge standards in an area, wastewater treatment may also become a more common feature of medical waste incineration systems. This could add significantly to the capital cost of an incineration system utilizing wet scrubbing (e.g., a wastewater treatment system can cost $150,000 (8)). However, a condensing wet scrubber system with zero liquid discharge, a technology used for hazardous waste incineration, is being adapted for application to medical waste incineration. It appears that this could be an efficient and cost effective system for controlling emissions from medical waste incinerators (2).

These scrubber systems can control dioxin and furan emissions as well as particulate emissions because dioxins and furans in flue gases condense onto fly ash particles if the gases are cooled enough. They are then removed by the scrubber or particulate control system (1 16). In MSW incinerators, the combination of a dry scrubber and baghouse can remove 97 to 99 percent of total dioxins present in postcombustion flue gases (1 16).

As noted, the proposed regulations in California first identified a dry scrubber as BACT[18] The incineration industry reported, however, that the dry scrubber/baghouse combination is not suitable for all medical waste incinerators, although this appears to be primarily based on cost considerations. As one study concluded, “Venturi [wet] scrubbers, due to their lower capital costs and greater flexibility, are the best choice for smaller and medium size hospital incinerators’ and dry scrubbers, while ‘‘not as popular or as proven in the field, ” are cost competitive for larger facilities (12 tons per day or more) (26).

[17] This is true unless zero risk is required, which no technology---or waste management practice—can achieve.

[18] California used EPA data on dry scrubbers used for MSW incinerators (usually a spray atomizer-baghouse system) to medical waste incinerators. Medical waste incinerators which do use dry scrubbers usually have dry injection baghouse systems with injection of a dry alkaline substance into the flue gas, which reacts with pollutants and is then captured in the baghouse (41).

Table 7—Performance Data of Medical Waste Incinerators With Pollution Control Equipment

Emission measured	"Typical" average of three samples	Lowest reported	Units of measurement
1. Particulate including Method 5 impinger catch, without CHEAF installed	0.028	0.018	Grain/sdcf @7%02
	69.2	44.5	mg/Nm³dry @7% O_2
	89.0		% Removal
2. Particulate including Method 5 impinger catch, with CHEAF installed	0.014	0.008	Grain/sdcf@7?4002
	34.6	19.8	mg/Nm³dry @7% O_2
	97.3		% Removal
3. HCl (hydrogen chloride)	9.2	0.98	ppm (vol) dry basis @7% O_2
	15.0	1.6	mg/Nm₃dry @7%O_2
	99.3		% Removal
4. SO_2 (sulfur dioxide)	4.0	0.31	ppm (vol) dry basis@7Y002
	11.4	0.89	mg/Nm³dry@7% O_2
	92.1		% Removal
5. CO (carbon monoxide)	18.8	8.7	ppm (vol) dry basis @7% O_2
Note: Worst case reported is 68 ppm (vol) dry basis @77002			
6. HF (hydrogen fluoride)	0.08	Not detected	ppm (vol) dry basis @7% O_2
	0.094	—	mg/Nm³dry @7% O_2
	95.6	—	% Removal
7. As (arsenic)	<0.05	—	mg/Nm³dry@ 7Y002
8. Be (beryllium)	<0.25	—	fg/Nm³dry@ 7% O_2
9. Cd (cadmium)	1.02	0.96	fg/Nm³dry@ 7% O_2
10. Cr (chromium)	0.045	0.03	fg/Nm³dry @7%O_2
11. Ni (nickel)	0.112	0.06	fg/Nm³dry@ 7Y002
12. Pb (lead)	10.74	5.82	fg/Nm³dry@ 7?4002
13. Hg (mercury)	2.96	1.86	fg/Nm³dry@ 7%O_2
14. TCDD equivalent (dioxins)	0.0311	0.0264	fg/Nm³dry@ 7%02
15. TCDF equivalent (furans)	0.1088	0.0967	fg/Nm³dry@ 7%O_2
16. Total TCDD & TCDF as TCDD equivalent	0.1399	0.1231	fg/Nm³dry@ 7%O_2
17. Opacity	2	0	Percent

NOTE: These data were collected from over 20 installations of medical waste incinerators with scrubbers in the United States in the period from Jan. 1,1988 through Apr. 1, 1990. They do not necessarily represent the best performance which can be achieved, but do represent "typical" performance which can be expected from the equipment and systems reviewed by the study. Some data are supported by over 100 separate samplings, while some (including the detailed metals and dioxin information) are based on only one or two installations with three samplings each. Nm³ represents normalization of measurements to standard 70/. 0, conditions. 1fg=10⁻¹⁵ grams.

SOURCE: Anderson 2000 Inc., Technical Description, Performance Information, Material Balance and Flowsheet Data, Typical Guarantees and Turnkey Installed Pricing for a 16.2 MM BTU/HR (1700#/HR) State-of-the-Art Medical Waste Incinerator With Wet Scrubber Emission Controls, Document #1-5670-W (Peachtree City, GA: Anderson 2000 Inc., 1990).

EPA reports that there are no technical reasons why a dry injection system or a spray dryer system cannot be applied to medical waste incinerators (41). Reports that the baghouse in medical waste incinerator applications is susceptible to corrosion because of the intermittent operation, which can result in holes in the bag, should not occur if the system is properly designed and operated (41, 49). Further, dry scrubbers do not have any associated waste water problems.

Wet scrubbers can remove about 95 to 99 percent of HC1 and 85 to 95 percent of sulfur dioxide emissions in MSW incinerator applications (116, 45). Wet scrubbers can achieve 90 percent HCl removal with plain water in medical waste incinerators, but lime slurries or caustic soda solutions can result in 99 percent or better hydrochloric acid removal (139, 126). The California Air Resources Board reports 85 percent particulate removal, 99 percent hydrogen chloride removal and O to 75 percent cadmium removal by wet scrubber systems for a medical waste incinerator (108). Reheating the flue gases may be necessary to ensure adequate dispersion from the stack and compliance with ambient air quality regulations, although it is not clear that any medical waste incinerators have had to do this (41).[19]

The WCEI maintains that advanced (versus conventional Venturi) wet scrubbing systems can attain high removal efficiencies for fine particulate, acid

[19]That is, wet scrubbing cools the flue gases to the water sateration temperature which can be as low as 120°F. As a result, plumes leaving the stack do not rise very high which can increase ground level concentrations of pollutants (1 16).

gases and heavy metals at substantially lower maintenance costs than the dry scrubber/baghouse combinations (45). The industry anticipates that soon (possibly within a year) the zero discharge wet scrubber systems will be available (45, 2, 104). Yet, wet scrubbers in current use can require a high energy input to collect fine particulate, can suffer problems of corrosion and erosion problems and reentrainment of particulate, and may produce a visible steam plume. Insoluble gaseous organics are not controlled and permits for some local sewer districts may be necessary prior to wastewater discharge (126, 139).

Removal of HC1 and sulfur dioxides in one dry scrubber system for a MSW incinerator were reported to be 90 and 70 percent, respectively (1 16). It is not clear how comparable these results are to those that could result from medical waste units. The California Air Resources Board reports 99 percent particulate removal, 85 to 95 percent HC1 removal, and 99 percent cadmium removal by a dry scrubber with a baghouse system for a medical waste incinerators (108).

Again, the type of waste burned in a unit and the size and type of incinerator unit are key factors in determining how appropriate a particular application of pollution control will be. In the types of modular incinerators used for most medical waste incineration, it appears from the California report that dry scrubbers with fabric filters are effective in controlling particulate, cadmium, and dioxin emissions (49). EPA is testing inlet and outlet emissions for both a wet and a dry scrubber system to determine their performance in controlling metals and dioxins as part of their NSPS testing program for medical waste incinerators (41).

In the past, manufacturers and users have preferred wet scrubbing systems (104). EPA reports that the current trend for large, new medical waste incinerators, at least in the States with more restrictive air standards, favors dry injection/baghouse systems (41). It appears that more testing of both wet and dry scrubbing systems and other pollution control technologies is needed to determine the best treatment technology for a particular setting. Indeed, some companies are experimenting with dry/wet hybrids which are ''customized' versions of these systems to presumably best meet a particular facility's needs (56, 104).[20]

It should also be noted that presorting waste to remove non-combustibles and substances known to contribute toxic compounds (see ch. 2) and allow for completeness of combustion (i.e., minimizing carbon monoxide and hydrocarbon emissions) are important factors affecting air pollutant emissions from incinerators. In fact, these factors can be considered complementary approaches for controlling emissions via applications of air pollution control technologies (1 16). Additionally, well-trained operators can monitor and control combustion efficiency to limit combustor emissions.

OPERATOR TRAINING

Fundamental to the proper operation of incinerators are trained operators. In addition, satisfactory equipment (e.g., proper design, controls and instrumentation, etc.) plus regular maintenance and repair are key components affecting performance (1 14). It is widely suspected that operators of medical waste incinerators are not routinely receiving proper training, and this, in part, explains why many incinerators perform poorly.

Recently, a number of efforts have been undertaken and/or completed that will facilitate operator training and improved operating practices. EPA has published a two-volume hospital incinerator training course and a handbook on the operation and maintenance of hospital medical waste incinerators (127, 131). The stated purpose of the volumes is to provide the operator ''with a basic understanding of the principles of incineration and air pollution control" (127). The presumption is that site-specific, hands-on training of operators will also occur.[21]

Some States (e.g., New York) have recently adopted requirements for certification of operators (94). The American Society of Mechanical Engineers is also developing an operator's certification program (6). The Waste Combustion Equipment Institute endorses the development of a national operator training and certification program (45). Most of these programs suggest various levels of

[20] Tests of one facility with a hybrid dry/wet scrubber system reportedly met the stringent Swedish dioxin emission limit levels (66).

[21] It is interesting to note that although worker safety issues are discussed in the EPA course, the importance of front-end separation of recyclable or noncombustible materials are not covered, and issues related to ash management are addressed only briefly.

training and competence for operators to achieve certification. In addition, privately published handbooks are also available to facilitate operator training (e.g., 32).

OFF-SITE INCINERATION

Off-Site v. On-Site Treatment

There was speculation after the passage of MWTA about whether the exemption from tracking requirements for wastes treated on-site (which meet the specified regulatory requirements) would encourage use of on-site incineration. This may not occur, given that other conditions (e.g., increased expense and/or space limitations to expand existing facilities, limited on-site expertise in waste management, etc.) may provide strong incentives for off-site treatment. It was in light of these conditions, which exist widely, that the prospect of an increased number of regional incinerators or other types of regional treatment facilities has also been predicted in recent years. It is not clear whether there is a trend for more off-site or continued on-site incineration.

A trend toward more off-site incineration may occur if changing requirements for waste management make it more advantageous for medical facilities than on-site incineration. Yet, health-care facilities still tend to favor on-site treatment because they have control over the ultimate disposal and can thereby limit their liability more easily. In addition, properly designed, operated, and maintained on-site facilities can meet emission standards and provide a viable waste disposal option.

At a minimum, it appears that present circumstances will stimulate cooperative planning efforts on a regional basis, whatever type of on-site or off-site treatment technology or management strategy is actually adopted.[22] The two basic types of off-site incineration options are: co-incineration of medical wastes with other types of waste (e.g., MSW) or regional incineration facilities dedicated to medical wastes.

Co-Incineration or Co-Firing of Wastes

To date, most off-site incineration has been in units dedicated only to burning medical wastes. Usually, capacity at off-site facilities is at such a premium that companies do not want to use the incinerators for nonmedical wastes. Yet, several MSW incineration systems, operated by different companies, do accept or are considering accepting medical wastes because they have excess capacity and/or the potential revenue from these sources is much higher than from MS W (104).23 In fact, some MSW facilities have marketed their ability to incinerate medical wastes (e.g., locations in South Carolina and Oklahoma).

From a technical perspective, MSW mass-burn incineration systems are presumed adequate to render medical wastes noninfectious (although no data on this was found) and their pollution control equipment should effectively control toxic compounds contained in it.[24] Concerns have been raised about the ability of some MSW incinerators (e.g., water-wall types) that may not attach a sufficiently high temperature throughout the chamber to ensure pathogen destruction in infectious medical wastes (45).

The number of co-incineration efforts is not high for a variety of reasons, including: 1) public concern over the ‘‘importation of medical waste from non-local areas; 2) employee concern over potential exposure to medical wastes in the workplace; and 3) mechanical considerations, such as the handling system for MSW (in which ‘‘red bags’ can be ruptured when a crane lifts them from the pit to the feeder of the incinerator, risking worker exposure) and the roller grate system in MSW facilities, which cannot control the movement of certain items well, such as needles and syringes (104).

More recent attempts at co-incineration of MSW and medical wastes attempt to address these issues by having a separate feed system that lifts intact medical waste packages into a dedicated medical waste hopper for the incinerator. Such systems are used in some on-site applications of incineration as well, particularly in a facility where heat is recov-

[22] It should be noted that regional, commercial autoclave units also exist in some areas and are being proposed in other areas.

[23] In most cases, MSW tipping fees at incinerators are much lower than medical waste fees (104).

[24] Difficulties, primarily related to greater occupational risk, associated with attempts to manage medical waste at refuse-derived fuel facilities have been reported (10). Questions have also been raised about the ability of MSW incinerators to handle needles and liquid wastes (given their grate design) and the possibility for greater pathogen survival given the typically cooler water walls associated with MS W (heat recovery) chambers (41).

ered. Another strategy is to use dedicated incinerators for medical wastes at sites permitted for MS W incineration (104). Sweden and the Federal Republic of Germany take a similar approach. In addition to permitting the use of high-volume MSW incinerators for medical waste, these governments allow co-locating infectious waste incinerators with MSW incinerators and channeling their flue gases through the high efficiency air pollution control equipment of the larger incinerator (57).

A variation of co-incineration is a demonstration project sponsored by the Department of Energy-Morgantown Energy Technology Center and Pennsylvania Energy Development Authority which co-fires medical waste with coal in a circulating fluidized bed with steam recovery (27). Suggestions have also been made that medical waste regional facilities configured as hazardous waste incinerators (which burn at extremely high temperatures) could be efficient enough to cofire hazardous or other "problem wastes" with medical wastes. Waste types suggested for co-incineration with medical wastes include: household hazardous waste, scrap tires, and some commercial waste (66). To date no such co-incineration facility exists.

There are plans for a hazardous waste (rotary kiln incinerator) facility in California to burn medical as well as hazardous waste. This facility is in the permit process and has an expected start date in 1992 (104). In some European countries, MSW and medical waste facilities are sometimes designed as hazardous waste incinerators (57).[25]

Regional Incineration

Regional facilities for medical waste management may be privately owned and/or operated, or may be cooperatively owned and/or operated by a number of generators. It is also conceivable that, as with MSW incineration, some of these facilities might be run by a municipality or by a municipality in conjunction with a private company and/or a number of generators (31). Regional incineration of medical waste on a commercial basis began in earnest in 1986, when the demand for services was high, capacity was scarce, and permit requirements for air emissions controls were simple and uniform (104).

In the four short years since then, the aggressive pursuit of permits and development of facilities by waste management companies have made greater capacity available, even though the regulatory climate for permitting such incineration has become complicated and variable. Indeed, the more complicated regulatory situation for incineration of medical wastes is one reason the demand for off-site treatment has remained high. At this point, hospitals and large generators in at least two metropolitan areas, Baltimore and New York City, are cooperatively planning a regional facility, usually as part of a broader planning effort for a regional waste management strategy. This section discusses these different approaches to off-site, regional incineration of medical waste: commercial (privately run) regional incineration and generator-run regional incineration.

Commercial Regional Incineration

The two largest waste management companies in the United States, Waste Management, Inc. and Browning-Ferris Industries, have aggressively developed medical waste incineration sites on a national basis; a number of other smaller companies (e.g., Medigen, Atwoods, and Incendere) have done the same on a more regional basis (104). As the conditions for permitting these facilities have become more problematic, closer scrutiny is being given to the size, type, and location of the regional sites. The waste management industry has called for a ' 'leveling of the playing field, " i.e., for uniform performance standards on a national basis in order that companies operating in more than one State will have similar requirements to meet. In addition, on-site and off-site incinerators would be subject to the same requirements; a state of affairs which can favor a larger scale operation (104).

Permitting is a long, difficult process for any facility—an-site or off-site—whether it be for medical wastes, MSW, hazardous wastes, or low-level radioactive wastes. Yet, for medical waste incineration, it is probably more difficult to permit an off-site than an on-site facility, although the on-site facility might operate quite similarly to the off-site facility (e.g., accept wastes from other generators). On-site incineration has the benefit of possible waste heat utilization and reduced transportation of waste. Indeed, some waste companies have attempted to locate on the site of a hospital or large generator.

[25]A facility that burns MSW and medical wastes in Stroud, Oklahoma, is also equipped m a way similar to a hazardous waste facility.

Three significant hurdles in the siting and permitting of off-site, commercial incinerators are: addressing public concerns over potential risks posed by incineration, meeting zoning permit requirements and addressing transportation issues (e.g., the ‘ ‘importation’ of wastes for the facility).[26]

The lengthy and difficult nature of the permitting process has had a dramatic impact on the economics associated with the construction of a regional medical waste incinerator. Permitting a site can take up to two years or more to complete before construction of a facility. This can encourage the construction of larger facilities or multiple facilities on a site.

Other factors can favor siting smaller units. For example, some communities are willing to accept a smaller facility that will manage their own community’s or local region’s medical waste, but are opposed to a facility that acts like a magnet for the importation of wastes from great distances. Also, depending on the service needs of an area, having several facilities rather than one large unit will provide convenient backup capacity when a unit is down for maintenance or repairs (104). It appears that a mixture of large and small facilities will be constructed depending upon the type of company operating each, the scope of intended service, and receptivity of the local community (104). It is likely that the developmental trend of regional incineration facilities for medical waste incinerators will mirror somewhat the ups and downs of the regulatory climate, at least until that becomes more uniform and certain in nature.

Nonprofit/Generator Regional Incineration

Although the number of cooperative arrangements between hospitals and other medical waste generators within regions is not as high as some might have predicted a few years ago, several such arrangements are being developed in different areas of the country. Examples include: the Baltimore area medical waste project; the Greater New York Hospital Association plans for a facility for metropolitan New York, and the facility planned by the Nassau-Suffolk Regional Council on Long Island, New York.

The Baltimore regional facility is designed somewhat like a utility, A number of factors led to the particular regional approach taken in this area. Hospitals were responding to a dramatically changed climate for medical waste management brought on by the media coverage of washups of syringes in the Baltimore area and related public concern, new State and local regulations that resulted, and consequent concerns over the viability of present management practices by various facilities (given, for example, a newly instituted ban of medical wastes by a local MSW incinerator, a moratorium in one county on incinerator construction, etc.).

The Maryland Hospital Association at the request of its members then solicited bids for a long-term solution to the medical waste management needs of the area hospitals (25).[27] These efforts were soon re-directed when a newly organized corporation, the Medical Waste Associates (MWA), presented a proposal to develop a privately-owned medical waste disposal facility. Eventually, to secure a freed cost for financing the facility, ‘‘tax exempt’ status was obtained for the $24 million bond issue. The central features of the arrangements between MWA and the individual hospitals are that participating generator facilities will sign ‘ ‘put or pay’ contracts (i.e., each hospital agrees to pay for the disposal of a minimum number of tons of waste per year) for 20 years (with renewal options every 4 years), and MWA will charge a flat rate of $300/ton ($0.15/pound) for their disposal privilege. A rebate arrangement exists to share the profits of ‘excess’ capacity sold to others, and MWA will pay the ‘‘founding’ hospitals 50 percent of any net profits earned from cogeneration activities (e.g., sale of byproducts such as steam, ash, etc.) (25).

The facility will have a 160-tons-per-day capacity in two incineration units; 120 tons are reserved for the participating hospitals. This facility will accept only medical wastes, including wastes from offices of doctors on the staffs of a participating hospital. Hospitals find it attractive that the facility will accept nonsegregated medical wastes, but this feature and the ‘‘put or pay’ nature of the contract create little incentive for reduction and recycling

[26]Public concern over the siting of medical waste facilities and the importance of public involvement in the permitting and siting processes are topics beyond the scope of this effort. Public concerns and the impacts of participation are not dissimilar to those expressed for MSW facilities that are discussed in OTA, 1989, see especially, chapter 8 (1 16).

[27]Cooley and Born (25) provide a more detailed account of the development of the Baltimore regional medical wrote facility.

efforts. There are 31 hospitals in the region to be serviced by the facility (as restricted by a special city ordinance). Construction began on the facility in the spring of 1990; it is expected to open in 1991.

The Greater New York Hospital Association has formed a cooperative to build a state-of-the-art facility to service the participating hospitals in the metropolitan New York area. Citizen and environmental interests, unions, waste companies, and city and State officials, as well as the generator interests, are involved in the planning of this facility as part of their development of a broader medical waste management plan. The New York City Health & Hospitals Corp. initiated a related but separate effort for a comprehensive waste management study to evaluate the potential of waste reduction and recycling opportunities for area hospitals before determining the most appropriate type of regional incinerator. The Natural Resources Defense Council hosted an initial meeting of interested parties in their New York office, November 30, 1989, to discuss some of the initial study plans for developing the regional medical waste management plan.

This plan also sets targets to reduce the volume of medical waste, explores toxicity reduction efforts, and identifies feasible recycling opportunities for hospitals. A critical feature of the planning is ensuring that the sizing of regional incinerator facilities factors in the impacts that reduction and recycling efforts might have on capacity needs in an area.

The Nassau-Suffolk Hospital Council, Inc. represents 22 nonprofit hospitals on Long Island, New York and also has been in the process of establishing a nonprofit corporation for a regional disposal facility, This regional planning effort, as with the metropolitan New York effort, includes efforts to implement reduction and recycling services in the hospitals. At this point, the council has adopted an interim strategy that involves use of autoclave/compaction units (see ch. 3) by the hospitals on-site and then shipment to several existing community MSW incinerators with excess capacity. A regional medical waste incinerator is still planned for the future, and sites for it are being investigated now (68).

Community involvement in the development of plans such as these is key to their acceptability. For example, the disinfection of wastes prior to shipment to the off-site incinerator can allay community concern over the transportation of the wastes. The entire load of waste (which is mixed in the compaction process with nonregulated medical wastes) is manifested to meet the requirements of MWTA. As noted above, there are no technical reasons to preclude the burning of medical waste in MSW incinerators. The pollution equipment on a state-of-the-art facility should adequately control emissions from the medical wastes. Adjustments can be made to facilitate safe handling of the wastes to minimize worker contact and any risks associated with exposure. In the case of the Long Island hospitals, pathological wastes and sharps will not be sent to the MSW incinerators, but instead sent to an upgraded hospital incinerator. This interim plan allows the closure of 11 older incinerators, which would not meet New York State new standards taking effect in 1992 (68).

SUMMARY

Incineration of medical waste is likely to remain, at least for the next decade, the cornerstone of management methods for medical wastes in much the same way landfilling is for MSW management efforts. Yet, as has already occurred with MSW management, this necessary and appropriate treatment option for certain wastes can be effectively supplemented by other treatment technologies (e.g., autoclaving, chemical/mechanical disinfection, etc.). The size, type, and nature of pollution control equipment will continue to change as the regulatory issues evolve. There is general agreement among regulators and the regulated community that development of uniform regulatory standards for air emissions and site permitting would help stabilize the regulatory climate for medical waste management and assist in the further identification and assessment of risks associated with incineration. In addition, regulatory determinations regarding the management of incinerator ash are necessary to accurately project costs for ash management and facilitate decision making by health-care facilities regarding the attractiveness of the incineration alternative on the basis of costs.

A number of management issues associated with packaging, handling, and disposal practices interface with decisions regarding treatment methods for medical waste. This chapter examines management developments for a number of such treatment issues: sharps management, small generator management, sewer use, and shredding.

SHARPS MANAGEMENT

Special attention is given to the management of sharps (e.g., hypodermic needles and syringes; also scalpels, broken glass, etc.) because of both the occupational and general public risks they pose. Sharps, specifically syringes, are generated by both households (e.g., in-home health-care) and health-care facilities. They are therefore part of both the general MSW and medical waste stream. In Washington State's survey of occupational exposure of waste industry workers to infectious waste (with 438 of the 940 workers surveyed responding), 21 percent of the respondents reported having sustained a needlestick injury on the job from both medical and residential sources (139).[1] The ATSDR, based on its literature survey and study, estimates that 500 to 7,300 medical waste-related sharp injuries occur annually to solid waste workers (93). Surveys of health-care workers, including housekeeping staff, usually indicate much higher incidence of needlestick injuries.[2] Sharps cause concern not only because of their infectious potential, but also because of the direct prick or stab type of injury that can result from them (114; see also 96). It is in part for this reason that EPA included unused sharps in its definition of regulated waste types under MWTA.

Most of the concern over the management of sharps has focused on the packaging of used sharps, the integrity of which is critical to containing the sharps during their collection, storage, and transportation to the treatment or disposal site. Currently, puncture-resistant containers are the preferred handling package for sharps (122, 118, 120, 121). Yet, a number of new techniques for containing sharps, particularly needles and syringes, continue to emerge (e.g., encapsulation).

Education of health-care and refuse workers, as well as the general public, about the proper disposal of sharps will facilitate their safe handling and management. Segregation of sharps and their separate collection and management without compaction is key to reducing the risk of injury associated with their management. In King County, Washington (Seattle area), there is a local requirement that all sharps be segregated and disposed of in leakproof, impermeable plastic containers with tight lids for separate, uncompacted collection and transportation to a landfill. This management strategy greatly reduces the risk of human contact with the sharps and the potential of needlestick injuries (111).

Manufacturing

Some of the efforts to ensure the safer handling of sharps have been made at the manufacturing stage. The attempt by manufacturers of sharps is to incorporate into the syringe a mechanism which will render it "nonsharp' immediately after it has been used. One method for achieving this is a sheath around the barrel of the syringe that will slide up around the needle when used while the barrel part is held. This makes it impossible for a needlestick injury to occur and the end product can be disposed of in a bag with other regulated waste items (unless the facility's protocol dictates otherwise) (104). These syringes are costly, however, restricting their use to date to high-risk areas of health care. Their potential as a feasible and practical method of protection in the home health-care setting seems apparent, although this application has not yet occurred, presumably due to their higher cost (104). Tests of the performance and reliability of these syringes were not identified by OTA.

[1]Interestingly, 32 percent of the respondents reported direct contact with waste blood on their clothing or shoes and 74 percent reported having received occupational cuts and scratches (139). Needlestick injuries while prevalent are not necessarily the most common type of occupational hazard for waste workers (e.g., back strain and other types of injuries are more prevalent).

[2]One survey by a local union of the Service Employees International Union (the Nation's largest health-care union) of its hospital workers in the San Francisco area, found that 62 percent reported accidental needlestick injuries on the job (100; see also 91).

Mechanical/Chemical

Although grinding, clipping, and other practices are no longer used for sharps management, primarily due to their potential for worker injury or exposure through aerosolization of microorganisms during the procedure, new techniques have appeared, e.g., chemical treatment and shredding of sharps. The primary alternative method of sharps management of this sort is the mechanical/chemical disinfection process discussed in chapter 3. In another process the needle part of the syringe is placed in a box while holding the barrel part. The needle completes an electrical circuit that melts it and leaves only the barrel in need of disposal. This process is a bit time consuming given the individual treatment of each sharp, but it does probably meet the "treated and destroyed" criteria of MWTA (141). Again, it may be a process for which the application to small generator settings is most practical (104).

Encapsulation

Another process introduced within the last couple of years that is experiencing some success is encapsulation of sharps. This process involves use of a phenolic solution to disinfect sharps and then introduction of an oxidizing agent as a catalyst to encapsulate the waste in a polymer matrix, i.e., a solid block-like material. This material can then be disposed of as solid waste without risk to the workers handling it (114, 104). It does not, however, meet the ''treated and destroyed' criteria of MWTA regulations (141).

This system is also expensive, currently four to five times higher than the cost of comparable containers for sharps (104). This factor makes its application for high-volume generators largely impractical, but the process could facilitate handling sharps for the small generators and home health care since it both disinfects and immobilizes the sharps, allowing for their disposal with other solid waste.

Some States (such as California, where small generators are required to manage their medical wastes in an approved reamer) have endorsed the process and in some cases permitted its use as an alternative treatment technology. Until more States endorse this process, it is unlikely that it will gain widespread adoption (104).

Concern has been expressed over potential impacts of these blocks of encapsulated sharps to the solid waste stream, in particular over what significance (if any) incinerating them with other wastes would have. Where landfilling of the "blocks" is not allowed, the encapsulated sharps are in some cases shipped via the United Parcel Service (UPS) to a manufacturer of the process in Georgia (see below) (104).

Mail Shipment for Disposal

The mail shipment of wastes for disposal is an increasingly common practice. As noted above, encapsulated sharps are sometimes shipped by UPS. Apparently, they are one of the few types of waste that nonpostal shipping companies will accept because they are rendered noninfectious prior to shipment.

A number of companies now operating were created primarily to cater to the needs of small or rural generators for viable disposal options. They operate out of several States and accept waste shipments from generators and then transport the wastes to treatment facilities. A contractor to OTA identified such operations in four States: Indiana, New Jersey, Oklahoma, and Texas (104). One of these firms claims over 30,000 clients nationwide and transfers the material to an incinerator in yet another State (104).

Most States authorizing waste by mail mandate that their State requirements be met, even if the waste is being mailed out of the State. For example, California authorizes out-of-state shipment only if the waste is rendered noninfectious prior to disposal. International shipment is allowed also if the waste is treated frost in-state (104). Under MWTA, generators in States covered by the demonstration program are allowed through an exemption in the regulations to ship medical waste sharps through the mail, provided they meet the specified packaging requirements (40 CFR 259). This exemption is intended to encourage small quantity generators (e.g., doctors' offices) to dispose of medical wastes properly (141).

For the most part, most of the medical wastes shipped are sharps. Some tissues and laboratory specimens are mailed to laboratories for diagnostic purposes. Historically, laboratory samples, etiologic agents, and other medical items have been shipped through the postal service. Some basic postal packaging requirements exist and the practices have

been the subject of congressional hearings (e.g., 54 Federal Register 1197(.)).

Concerns have been raised not only about the potential hazard or at least negative perception associated with handling medical wastes and household mail through the same postal system, but also over the operation of these waste mail companies that essentially operate as transfer stations (104). The scope of current regulation does not cover such operations. These practices warrant further investigation, particularly over the adequacy of current regulations governing the shipment of wastes through the mail and the desirability of such systems for small generators and rural health-care facilities.

SMALL GENERATOR - MANAGEMENT

The amount of medical wastes generated nationally from non-hospital settings is not known (although EPA will reportedly be including such estimates in its first report to Congress). These small generators include such sources of medical wastes as: home health-care patients, doctors' offices (including dental and veterinarian), and rural health-care settings. Although some States are including some small generators of medical wastes, such as doctor and dental offices, in their regulatory programs for medical wastes, most exclude households.

The equity of including some and not all generators of medical wastes under regulations is hotly debated.[3] It is widely recognized that the same types of controls are not feasible for both large and small generators. The focus of the debate is over whereto draw the regulatory line between generators to be included or excluded from regulation and over how large the gulf should be between the level of scrutiny and degree of requirements for large versus small sources of medical wastes.

In the area of medical waste policy, the demand for a comprehensive scope for controls is being grappled with from the beginning of regulatory efforts. EPA issued guidelines for home health-care disposal shortly after it promulgated its standards for MWTA (130). Other guidelines are being developed and discussed in response to the increased attention to wastes from these sources and their infectious potential (102; see also 82, 83).

The need for developing feasible and economical treatment and disposal options for small generators is widely acknowledged. Few advocate including households under medical waste regulations, but concerns over solid waste worker safety are real. The need for viable disposal options for rural hospitals, small laboratories, and different types of doctors' offices are also real. Some technologies have already been adapted for nonhospital sources. For example, for a number of years a mobile sterilization system has been used in Berlin, West Germany, to collect doctor office and nursing home medical wastes. There are plans by a hospital council on Long Island, New York, to attempt to bring this technology to the United States (68).

For small generators, the most promising of the emerging treatment methods discussed in this report are the nonincineration treatment methods and the newer management methods for sharps. These options may provide safe and economically feasible on-site treatment alternatives for small generators. Off-site incineration is also an option, since some medical waste companies will contract to pick up and transport to their incinerator medical wastes from doctor and dental offices and other small generator sources.

Careful and creative management strategies will be key to ensuring effective handling and treatment of these wastes. Limited information and assistance are available to households, small and rural hospitals, and other smaller generators to help them devise effective medical waste management plans and systems. Education efforts are clearly important but to date are limited to an EPA brochure for households, to be distributed by health-care providers or others (130).

[3]Clearly, regulations are usually adopted not because they are perceived as "fair,' but rather because they are necessary to achieve some social or economic goal of the greater public. That regulations be "reasonable" maybe difficult to define, but a legitimate standard by which to judge them. In most areas of environmental policy, regulatory attention is first focused on the largest generators of the problem. Later, refinements are made to the regulations and their scope broadened to include other significant sources.

OTHER TREATMENT TECHNIQUES: SEWER USE AND SHREDDING

Sewer Use

Certain medical wastes can be legally discharged to sewers. These wastes include blood and blood products, ground-up solid infectious wastes (e.g., body parts and organs), and other liquid and or semi-liquid infectious wastes. Reportedly, about 23 percent of hospitals dispose of blood and body fluids to sewers and about 14 percent grind solid infectious wastes and discharge them to sewers using a grinder similar to that used for in-sink home garbage grinding (91). The State of Washington survey found that 49 percent of the hospitals surveyed reported pouring blood into the sewer system (139).

EPA (122), in its guidance manual for infectious waste management, identified sewers as an acceptable treatment option for blood and blood products if secondary treatment is available (i.e., occurs at the sewage treatment plant).[4] Secondary treatment systems, however, are designed to microbiologically breakdown and remove organic constituents in wastewater and are not designed to disinfect waste water. At a primary or secondary municipal treatment facility, wastewater disinfection occurs as the last step, usually by chlorination, prior to release to the environment (11 1).

While there is little concern over the ability of sewage treatment plants to handle liquid medical wastes adequately, the absence of treatment at the point of discharge (i.e., at the facility) has prompted some concern.[5] Medical staff and plumbers risk occupational exposure if there is a sewage backup (104, 91). At least one such incident reportedly occurred in 1987 at the Los Angeles County-University of Southern California Medical Center when a pipe in the basement burst and dumped possibly contaminated blood and fluids on workers (five of whom filed a lawsuit against the facility).[6] This type of incident is an example of a plumbing problem and concern over potential worker exposure from these types of accidents should be distinguished from the issue of health-care facilities discharging body fluids to the sewage system.



Photo credit: Vetco Sanitec Corp., Combustion Engineering, Stamford, CT

Shredded medical waste meets the nonrecognizability requirement of MWTA. Shredders can be used for untreated wastes or be incorporated into the use of various treatment technologies. Shown here are contents of microwaved and shredded medical wastes.

Another aspect of sewage disposal that is much larger than the medical waste issue and its contribution to the flow of wastes to the sewers is potential problems associated with combined sewer overflows (CSOs), i.e., where sanitary and storm sewers are combined. In these situations when it rains untreated sewage and any wastes discharged to sewers may be discharged directly to waterways, because the sewage treatment plant cannot accommodate the increased flow of waste water. In New York City, for example, there are over 500 CSO points and for some as little as a quarter of an inch of rain can lead to the release of untreated sewage (134).7

Shredding

The nonrecognizability requirement of MWTA regulations has focused attention on methods to destroy treated waste, notably shredding, to meet this requirement. Currently, there are no criteria (voluntary or mandatory) on the degree of shredding

[4]Steam sterilization and incineration are, however, the two recommended treatment methods (122).

[5]This is true particularly when untreated discharged liquids can bypass the treatment facility in areas with combined sewer overflows.

[6]*Quinn v. Court of Los Angeles*, Case No. C669760, L.A. Superior Court of the State of California.

[7]CSOs were in fact implicated as a major source responsible for the beach washups of medical wastes in the summer of 1988. Investigations concluded that syringes discharged to the sewers, primarily from I.V. drug users and diabetics, were directly discharged to waterways in heavy rains and then other weather patterns made the likelihood of washups containing these wastes high (137).

required to achieve nonrecognizability. This lack may account for the apparent reluctance to apply shredding technology to emerging treatment methods.[8] The necessity for criteria or standards for this and other treatment and destruction methods will perhaps best be evaluated after the completion of MWTA demonstration program.

Yet other factors, such as the difficulty existing shredding systems have with the heterogeneity of the medical waste stream and the high maintenance associated with shredders, may account for their limited application to date. It may be that improvements and refinements to shredding technologies will occur, particularly if the nonrecognizability criterion is more widely incorporated into medical waste regulations, and the use of shredders is increased. In any case, disinfection of infectious medical wastes before shredding to minimize potential aerosolization of pathogens is desirable.

[8]Interestingly, there are specific shredding standards for document destruction by the Department of Defense for confidentiality (104).

Chapter 6

Comparisons of Treatment Alternatives

However great the achievements of reduction and recycling efforts, there will continue to be a need for effective treatment and disposal for wastes that cannot be recycled. Although incineration remains, and is likely to continue to remain, a primary treatment method for medical wastes for the foreseeable future, a number of other treatment alternatives are available and will supplement incineration technology. As concerns over the cost, safety, and permitting/siting of incineration facilities continue, so too will the favorable climate for emerging nonincineration technologies. New variations of autoclave, mechanical/chemical, radiation, and microwave treatment methods are now commercially viable. Other emerging technologies are in the testing or even conceptual stages. Currently, States play the critical role in evaluating and approving alternative treatment technologies. Inconsistencies exist among the States and increasingly Federal guidance on evaluation and approval of treatment alternatives is suggested as necessary and desirable (e.g., suggestions of participants at the OTA Medical Waste Workshop, 1990).

An important given when comparing alternatives is that whatever treatment alternative is used, some form of additional solid waste disposal must occur. In all cases, ultimately, some degree of dependency on landfills remains. For medical waste incineration, the ash becomes a waste product requiring landfilling. For autoclaving, microwaving, and irradiation either incineration and/or landfilling is necessary. The residue from the chemical/mechanical treatment alternative will be discharged to the sewer or landfilled. The difficulty of landfilling even treated medical wastes, given refusals by some landfill operators, remains a significant obstacle for management in some areas of the country. Interstate shipment and international exportation of solid waste, including medical wastes, is an emerging environmental and political issue nationally (1 16).

Valid comparisons of various treatment alternatives for medical wastes are problematic because different types of treatment goals are served by different technologies (e.g., the goal can be treatment to render wastes noninfectious; or noninfectious and nontoxic; or noninfectious nonrecognizable, and/or nontoxic). This means that different techniques may be appropriate for different waste types. Treatment alternatives will differ in the nature of the emissions that warrant test protocols, control measures and operating parameters specific to each technology.

Obviously, costs and risks associated with the alternatives will vary. Further, a number of considerations concerning liabilities and costs influence generator decisions about on-site versus off-site treatment. Treatment alternatives are more easily scaled to various types and sizes of facilities. Comparisons between off-site and on-site applications of various alternatives can also be problematic. With all of these differences, clearly, comparisons of the treatment technologies must be made carefully. Such comparisons are imprecise, but helpful in highlighting the various features and considerations associated with the alternative treatment technologies.

CAPABILITIES AND RISKS

Table 8 compares the various treatment technologies discussed in chapters 3 and 4. All of these treatment alternatives can effectively manage most infectious wastes; the only ones that are usually used to treat pathological waste are the incineration and mechanical/chemical disinfection systems. Depending on the type of incinerator and the nature of its controls, incineration is the one treatment alternative that could manage all of a health-care facility's wastes, i.e., pathological and other infectious, hazardous (possibly, depending on the design and controls of the incinerator), administrative, food, and other non-patient wastes.

From other perspectives, nonincineration alternatives may have advantages over incineration. In general, there are more serious emissions concerns associated with incineration than most alternatives. Yet, it is true that because incineration is a more established technology, emission concerns have been more clearly identified. The human health and environmental risks may be presumed to be less from nonincineration treatment alternatives but additional study, particularly of water effluents from some of the systems, is necessary. Generally, health risks associated with the various treatment technolo-

Table 8—Comparison of Treatment Technologies

Treatment technology	"Regulated medical wastes" appropriate for treatment method to render wastes non-infectious	Volume reduction (%)	Costs (approximate) [d] Operating or per pound charges (not including labor; depreciation; profit/ return) ($/lb./hr.)	Capital (equipment and installation) ($ K)
Steam autoclave	All, except pathological	o	$0.05-$0.07	$100 K (on-site)
Autoclave with compaction	Ail, except pathological	60-80%	$0.03-$0.10	$100 K
Mechanical/chemical	All	60-907.	$0.06	$40-350 K
Microwave (with shredder)	All [a]	60-907.	$0.07-$0.10 [b]	$500 K
Irradiation (with grinder)	All, except pathological	60-90%	$0.15	Not available
incineration	All[c]	90-95%	$0.07-$0.50	$1,000 K (on-site)

[a] Pathological wastes are usually not treated by microwave due to esthetic reasons. Cytotoxical or other toxic Chemicals cannot be adequately treated to reduce their hazardous nature.
[b] Including an energy cost of $0.07/kWh.
[c] Although separation of noncombustibles and items with problematic constituents improves combustion efficiency (See ch. 3).
[d] Reliable cost information is difficult to obtain and verify. Further, valid comparisons are difficult to make given the different circumstances under which various technologies operate (e.g., amount of waste treated and its effect on costs, etc.)

SOURCE: Office of Technology Assessment, 1990.

gies have not been thoroughly studied. Presumably, pollution controls could adequately control pollutants of concern for both nonincineration and incineration alternatives. Of course, the more pollution controls necessary, generally, the more expensive the treatment.

COSTS

The concern that the already generally precarious economic state of the health-care industry could be jeopardized by further regulation of medical waste management warrant s examination. Presently, the exact amount a health-care facility spends on medical waste management is often not known with certainty even by the facility's management. The additional cost that new controls, alternative treatment technologies, or management practices might entail can not be accurately assessed unless current costs can be understood with some certainty.

Available cost estimates for various treatment technologies indicate that on-site incineration can be comparable or significantly higher in costs than other on-site alternatives (30; 104). While costs for on-site alternatives can be estimated fairly constantly, the same is not true for off-site alternatives. OTA contractors found from informal discussions with generators of medical wastes and operators of medical waste services throughout the country that the price charged for any type of off-site treatment is never determined solely on the basis of costs, but rather by ''what the market will bear. ' Given that it is a highly competitive industry, this does not necessarily mean that off-site waste facilities reap an unusually high profit, but, as noted in chapter 3, the medical waste industry is healthy.

It appears that hospitals and other health-care facilities eligible to receive Medicare reimbursement can theoretically be reimbursed for some on-site medical waste management costs. Although there is no specific category for waste management reporting, some percentage of capital costs and some operating costs could be covered (54). In the State of New York the eligibility of health-care facilities for Medicare reimbursements for some on-site medical waste costs (and regional utilization of an on-site hospital treatment facility) is explicitly addressed by the Department of Health (85). Although no hospitals have been known to request Medicare reimbursement to date, it was part of the New York State legislative debate over increasing the reimbursement rates for hospitals (80).

Other types of grants offered by some State energy offices, such as those that will cover some portion of the capital costs for waste-to-energy facilities, may also reduce a facility's share of costs for this type of incineration (31). For example, in New York State, a proposed Environmental bond issue, which will be on the ballot in November 1990, will provide $50 million in State assistance for regulated medical waste projects. The grant program would be administered by the State Department of Health and would provide funding for up to 50 percent of the project costs. To be eligible, a facility must participate in a waste audit and must develop

a plan for recycling, product reuse, and waste reduction (94).

The volume of waste handled by a treatment unit and its effect on the operating cost of the unit is highly variable, but generally costs are lower for on-site incineration and nonincineration alternatives. The capital costs associated with incineration are significantly higher than those for most alternative treatment technologies. Yet, heat recovery (and, as noted, programs that will reimburse up to half the capital costs for waste-to-energy facilities) and efficient operation (e.g., including recycling in conjunction with incineration) may reduce incineration costs to the facility and result in a more favorable cost comparison of incineration to the other technologies (31). Nonetheless, the potentially high cost of disposal of incinerator ash, if it is classified as a hazardous waste, is also a potential significant cost factor associated with incineration that must be considered. Other factors that affect costs, such as reduced cost of transportation, reduced disposal costs, and reduced liability, are relevant to a decision to manage wastes on-site v. off-site.

Costs, even so, are only one of a number of factors (e.g., nonrecognizability, liability, and ability to render wastes non-infectious) that health-care facilities consider when deciding what type of treatment alternative to use and whether to manage wastes on-site or off-site. Clearly, a facility may be able to reduce its costs and liability and have greater control by managing wastes on-site; however, on-site management also represents a major institutional commitment of resources to waste management, which is not the primary function of the health-care facility. As has been noted throughout this report, a number of factors favor off-site treatment as well.

Ultimately, each generating facility must weigh the various factors and determine which waste reduction and management alternatives are most appropriate for its circumstances. Public policies should recognize and not preclude the variable solutions necessary to meet individual generators' waste management needs. In addition, medical waste policies should help through the use of some sort of protocols to reduce uncertainty over the reliability and safety of various treatment alternatives.

It remains to be seen what direction Congress and Federal agencies, and the medical and health-care industry and community will define for medical waste management. It will be important, though, that any legislative or regulatory activity acknowledges and appropriately addresses the variety of management issues and available treatment technologies discussed in this report. Experiences with management of other components of our society's wastes indicate that effective waste management is based on a recognition that there are a variety of viable management options available and appropriate to meet particular site-specific circumstances, and prevention or reduction and recycling efforts are included in these options. Adopting a more comprehensive approach to medical waste policy may offer the greatest prospect for adoption of a program that will ensure the safe, cost-effective management of medical wastes.

The Medical Waste Tracking Act

MWTA establishes a demonstration tracking system (Sections 11001-11003) and, as noted in the introduction, directs EPA and ATSDR to undertake studies of certain medical waste management issues (see box D).[1] Unlike any other environmental law, MWTA was designed to structure a process for gathering sufficient information to evaluate the nature and risks posed by a waste, so that Congress could then reevaluate and identify whether any further policy action is warranted. The intent of the law is to develop a basis for determining, after the completion of the demonstration program and the government-mandated studies, whether and in what ways the Federal Government should regulate medical wastes.

MWTA specifically applies to the Great Lakes States and Connecticut, New Jersey, and New York (Section 11001). All of the Great Lakes States were given the option to decline to participate in the demonstration program (and any other State was given the opportunity to participate); and Connecticut, New Jersey, and New York could petition out if their State had a program at least as stringent as that of the Federal Government.[2] None of the Great Lake States chose to participate, while none of the other three States petitioned out. Thus, MWTA applies only to New York, New Jersey, Connecticut, and also to Rhode Island and Puerto Rico, which voluntarily entered the program. Louisiana and the District of Columbia voluntarily joined the program, but later petitioned out of it.

MWTA defines medical waste as ". . . any solid waste which is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals. "[3] Section 1004(40) of RCRA, as amended by MWTA, notes further that medical waste "does not include any hazardous waste identified or listed under Subtitle C or any household waste as defined in regulations under Subtitle C.' Any solid waste mixed with a regulated (i.e., listed) medical waste (see below) is also a regulated waste under MWTA. As noted earlier, special regulations exist for the management of LLW (see box A).[4] MWTA regulations do require tracking of LLW medical waste, unless it is mixed with hazardous wastes that would be regulated under RCRA Subtitle C (40 CFR 259).[5] It should also be noted that domestic sewage is not included in the RCRA definition of solid waste (Section 1004(27)).

It is possible that the EPA definition of regulated medical wastes, codified as part of MWTA, might become more widely used and help forge consensus on the categories of wastes designated as infectious. These categories are now frequently referred to as "regulated medical wastes. Box D outlines the major features of the tracking program established by MWTA.

EPA cost estimates, although provided to EPA by the regulated community, are considered low by some waste industry officials and regulated sources (141). These estimates are that the cost to comply with MWTA will increase disposal of regulated medical wastes by approximately $0.08/pound on average; with average annual compliance costs per facility range, according to EPA, from about $3,750 for hospitals to about $70 for dentists (Fed. Reg., vol. 54, No. 56, Mar. 24, 1989). According to the preliminary results of the New York City medical waste study, while the per pound cost of medical waste disposal has remained relatively stable since MWTA passed, overall waste management has become highly costly. For example, ''a typical 500-bed acute-care hospital in New York City has experienced a 400 percent cost increase in waste disposal as a result of MWTA" with an actual cost ''in excess of $400,000 per year for such a hospital" (63). This could result from poor segregation practices at certain facilities and/or to shortages of personnel for such tasks.

Upon completion of the demonstration program, EPA and the participating States will review the generator reports and evaluate the program, including the impacts of the program on management practices and the costs of complying with the tracking regulations. As noted above, EPA's report to Congress on the program is due in September 1991.

The importance of MWTA demonstration tracking program to abating medical waste problems is not clear; if a more comprehensive regulatory program is adopted in the future, the contribution of a tracking system to the

[1]This discussion is based in part on that contained in (137); see also (36), (86), and (22).

[2]Independently, a number of actions have been undertaken by States to address medical waste problems (e.g., New York State and New Jersey cooperatively adopted a tracking system in August 1988 (before passage of the MWTA)). Also, the New York Bight Floatables Action Plan, a multi-agency effort led by EPA Region II, is part of the New York Bight Restoration Plan and addresses some medical waste handling procedures in the New York Bight area.

[3]There is a difference between this definition of ''medical waste'' in the MWTA and wastes identified as ''regulated medical wastes" (see ch. 1).

[4]The Low-Level Radioactive Wrote Policy Act of 1980 and the Low-Level Radioactive Waste Policy Amendments Act of 1985 (1 17).

[5]LLW medical waste, upon radioactive decay, would still have to be tracked as regulated medical waste, disposed of through the sewer system, Or treated and destroyed onsite, or tracked as a hazardous waste.

Box D—The Medical Waste Tracking Program

EPA established the 2-year pilot Federal tracking program authorized by MWTA by publishing its "Standards for the Tracking and Management of Medical Waste; Interim Final Rule and Request for Comments" in the Federal Register in March 1989, which took effect in June 1989.[1] The tracking system for medical wastes designates recordkeeping requirements for facilities that generate over 50 pounds a month of medical waste and requires the use of a four-part form for any off-she shipment of medical wastes. EPA and the State must be notified if a generator does not receive a copy of the manifest form from the final destination facility. Generators of medical waste that produce less than 50 pounds are subject to the same handling requirements, except instead of using the tracking form they must maintain a log (i.e., as a reporting requirement).

EPA has authority to assess civil penalties of up to $25,000 per day for each violation, criminal penalties of up to $50,000 per day per violation, and jail terms of up to 5 years may be imposed in States implementing the tracking system (sec. 11005). States have the authority to conduct inspections and take enforcement actions as well. The MSWTA does not specify whether the EPA or the States has lead enforcement authority and the EPA regulations do not specify enforcement roles, but the Agency prepared an enforcement strategy which encourages State implementation. Flexibility is given to the States to develop a variety of approaches to compliance and enforcement (134). EPA restricts its role to encouraging voluntary compliance through its various education efforts and by providing States with guidance and assistance when needed (e.g., when a violation involves wastes from or transported to a nonparticipating State).

EPA, also as part of the MWTA demonstration program, issued requirements that generators of waste must follow before medical wastes leave the site to be shipped to authorized treatment or disposal facilities. Under the demonstration program, generators include institutional and commercial sources of wastes in the participating States and territories. Of course, any treatment facilities accepting regulated medical wastes may be subject to other Federal, State, and local laws and regulations. The MWTA does not consider residential sources of medical waste to be regulated generator sources, nor does it address problems with the disposal of wastes associated with illegal drug use. EPA issued guidance information on proper home medical waste disposal and states in its pamphlet describing the MWTA that drug enforcement, Clean Water Act programs, and citizen litter control projects will help eliminate "flagrant dumping of wastes.' (130)

According to the MWTA requirements, generators must separate regulated medical wastes from general refuse, meet storage requirements (if such wastes are stored before treatment), and package regulated wastes in labelled, rigid, leak-resistant containers. In addition, special separation and packaging requirements are specified for both sharps and fluids. To help ensure that packages retain their integrity during handling and transportation, secondary packaging (i.e., a rigid outer container) is generally required for shipping. This secondary packaging can be reused if thoroughly cleaned. The package labels must identify the content, generator, and transporter of the wastes.

Medical wastes incinerated on-site, or treated by other methods (e.g., some type of disinfection unit) that meet both regulatory criteria of treatment and destruction (i.e., waste is "processed by a means to reduce levels of infectious agents" and waste is "no longer generally recognizable as medical waste"), do not need to be tracked under the demonstration program, but instead generators must submit a report to EPA. The position of the EPA is that if the biological and physical hazard of the waste, as well as their 'visually offensive nature," is altered they can be managed according to regulations applicable to solid waste. The required report must be a summary of the volumes and types of medical waste treated on-site during the first 6-month period of the program; a second report covers the 13 to 18 months of the program.

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[1] Since this time, the Agency has issued a number of guides for the public, generators and transporters about the Federal MWTA program (128).

improved management of medical waste will need to be evaluated independently. GAO (134) has evaluated the efforts to date of the EPA and States to implement MWTA. For this reason, their implementation activity is not evaluated here. Apparently, despite early controversy over the listing of wastes by the Agency to be tracked and concerns over compliance costs, as well as the initial type of confusion usually associated with new regulatory programs, the implementation of MWTA demonstration program has been rather smooth. EPA reports that most of the early violations were minor in nature (e.g., errors in completing manifest forms, etc.), although fines have been levied against responsible parties for such violations as incomplete record keeping and failing to lock storage areas (88).

A number of issues that EPA and ATSDR are required by MWTA to address (e.g., health effects of medical waste, generation information, cost implications, small-quantity generator issues) also is not discussed extensively in this study. The focus of this effort is on available and emerging management methods, including waste reduction and recycling possibilities. This emphasis on the evaluation of treatment technologies is intended to alleviate immediate concerns over the nature, availability, and tradeoffs of various treatment methods and to stimulate a broader consideration of management alternatives for medical waste than is currently typical.

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