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 solubility 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 ash, whereas other types of less volatile metals (e.g., aluminum, chromium, iron) are concentrated in bottom ash (116).

[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 (116) for a discussion of the current unresolved state of ash regulation at the national level.

[6] Although Waste Management, Inc. indicates that its testing of medical waste incinerator ash determined that the quality of the ash is similar to MSW incinerator ash (43). See OTA (116) 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 (116)]. 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 C—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 ng/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 ng/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 ng/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 ng/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 1,400°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 systems). 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 ng/kg achievable with a well-operated incinerator equipped with a high-efficiency Venturi (wet) scrubber (107).

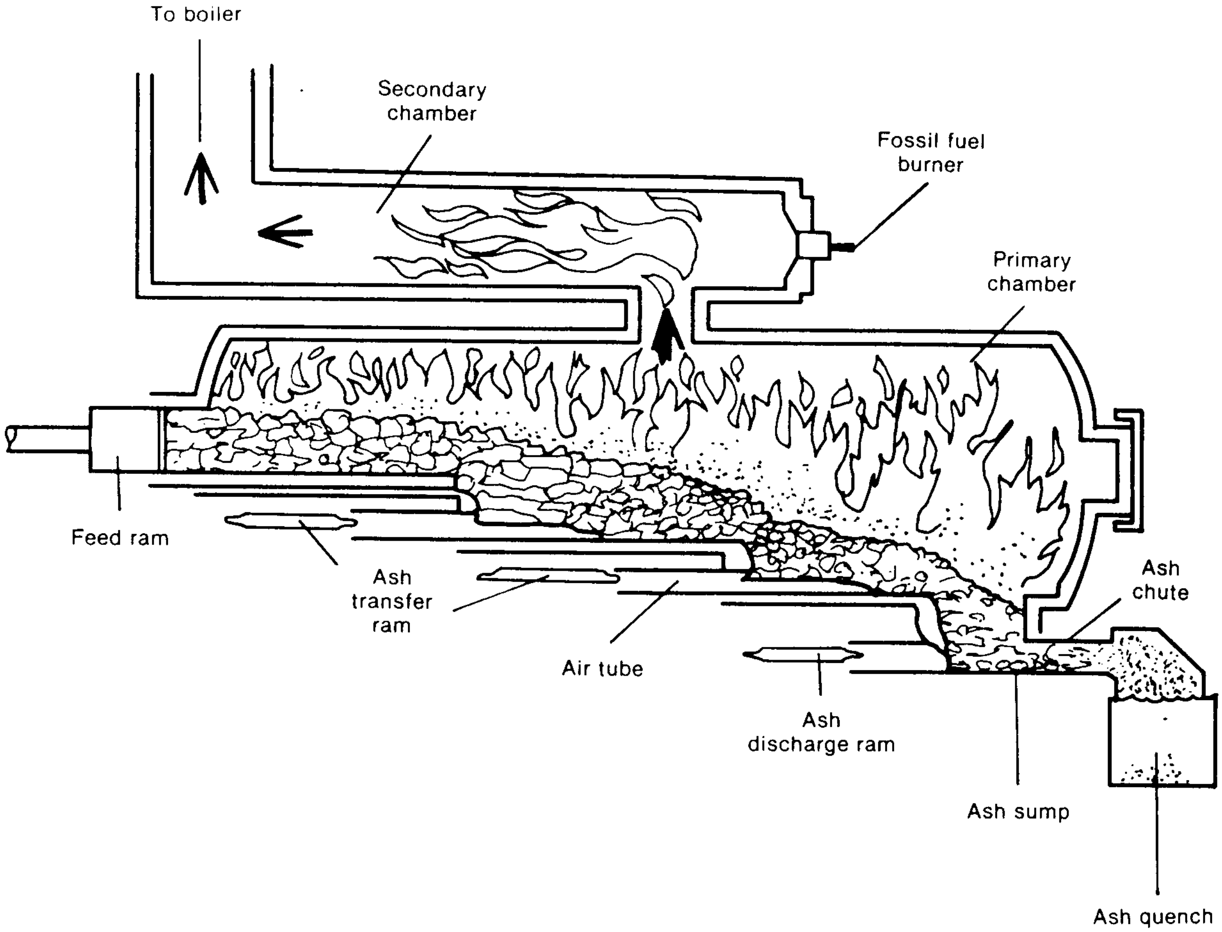
Given the large number of medical waste incinerators (on-site and off-site) operating in the country, separate regulation taking into account the special characteristics of these incinerators and the nature of the wastes they burn may be most appropriate.[10] MSW incinerators tend to be large, mass-burn 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 (114, 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 operating 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) that 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 HCl 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 (HCl), 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 lodge 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 HCl.[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.
[d]From table XII-10.

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 first 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.

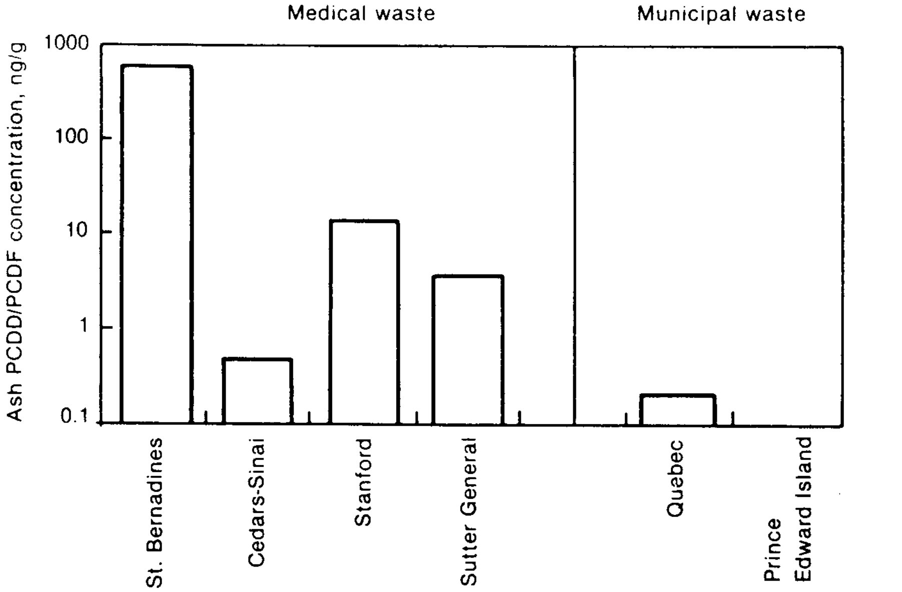
The results of the California risk assessment estimate for dioxins that the risk factor ranges from 1 to 246 in a million of developing cancer for continuous daily exposure for 70 years to an airborne concentration of one picogram per cubic meter of total dioxins. For cadmium, the estimate is that the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

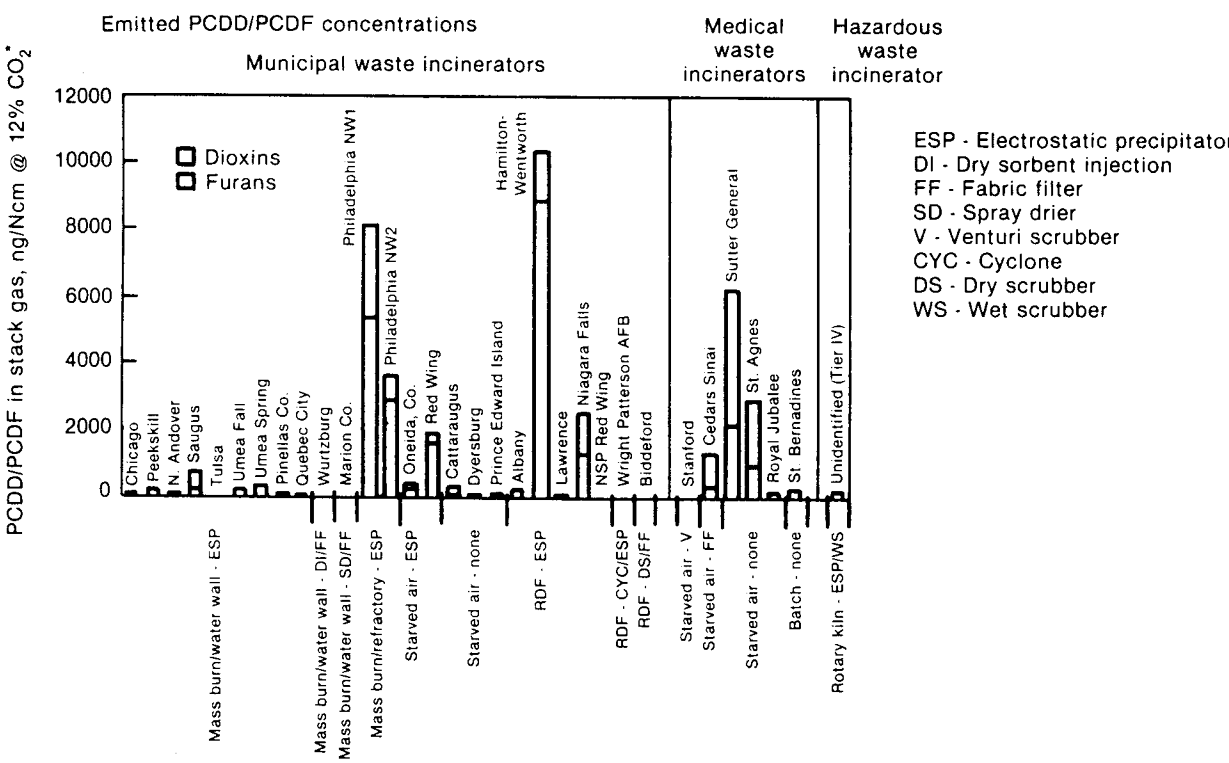
[16]The attachment (bonding) of dioxins/furans to solids, i.e., the ash, is such that their removal by leaching in a landfill is not considered significant. Thus, concentrating the dioxins/furans in residue allows for their control by landfilling (20).

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).

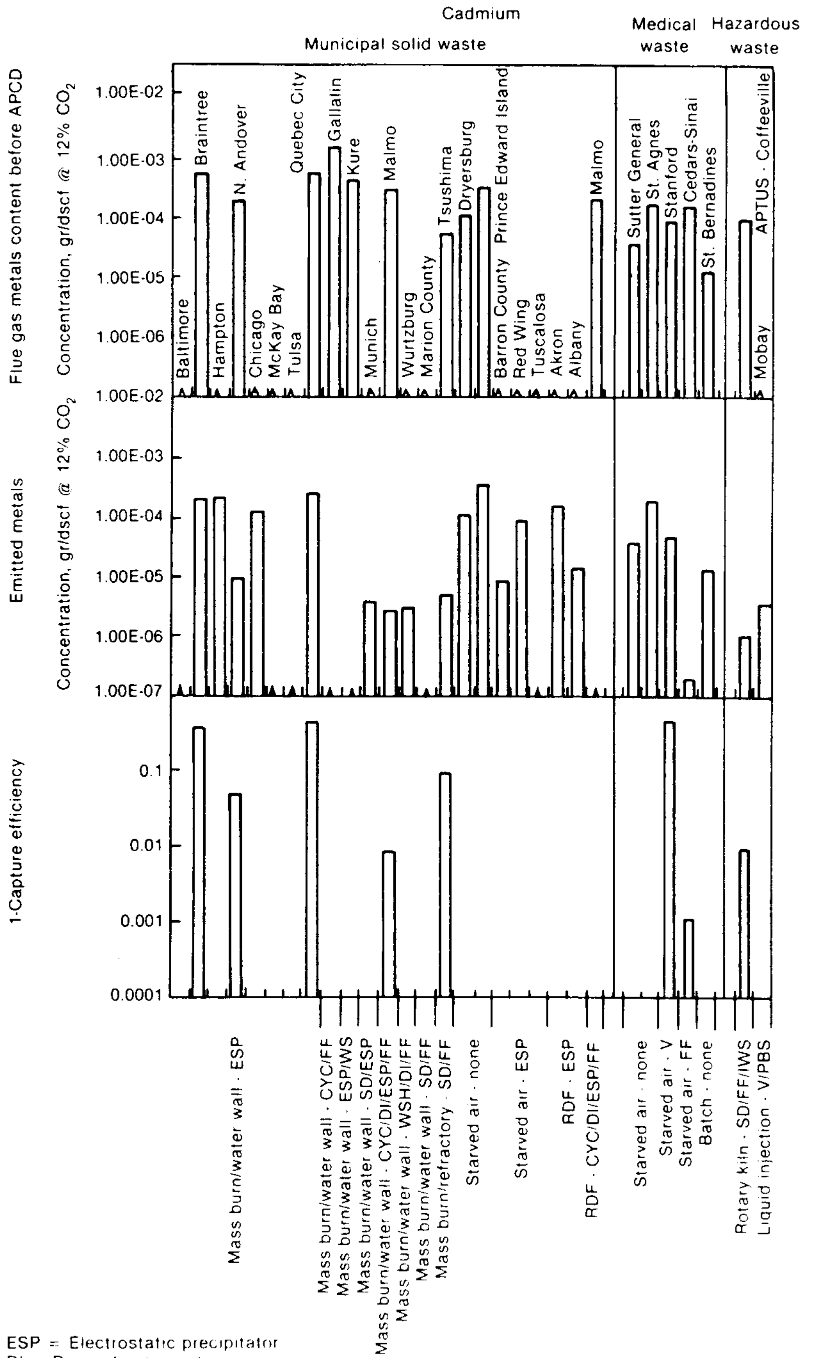
Figure 10—Comparison of PCDD/PCDF Emissions From a Variety of Incinerators



*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 Contract A832-155 (Irvine, CA: Energy & Environmental Research Corp., 1989).

Figure 11—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 filters) 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: particulates, 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 filter) 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 (116). 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 (116).

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% O_2
	69.2	44.5	mg/Nm³ dry @7% O_2
	89.0		% Removal
2. Particulate *including* Method 5 impinger catch, *with* CHEAF installed	0.014	0.008	Grain/sdcf @7% O_2
	34.6	19.8	mg/Nm³ dry @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/Nm³ dry @7% O_2
	99.3		% Removal
4. SO_2 (sulfur dioxide)	4.0	0.31	ppm (vol) dry basis @7% O_2
	11.4	0.89	mg/Nm³ dry @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 @7% O_2		
6. HF (hydrogen fluoride)	0.08	Not detected	ppm (vol) dry basis @7% O_2
	0.094	—	mg/Nm³ dry @7% O_2
	95.6	—	% Removal
7. As (arsenic)	<0.05	—	mg/Nm³ dry @ 7% O_2
8. Be (beryllium)	<0.25	—	fg/Nm³ dry @ 7% O_2
9. Cd (cadmium)	1.02	0.96	fg/Nm³ dry @ 7% O_2
10. Cr (chromium)	0.045	0.03	fg/Nm³ dry @ 7% O_2
11. Ni (nickel)	0.112	0.06	fg/Nm³ dry @ 7% O_2
12. Pb (lead)	10.74	5.82	fg/Nm³ dry @ 7% O_2
13. Hg (mercury)	2.96	1.86	fg/Nm³ dry @ 7% O_2
14. TCDD equivalent (dioxins)	0.0311	0.0264	fg/Nm³ dry @ 7% O_2
15. TCDF equivalent (furans)	0.1088	0.0967	fg/Nm³ dry @ 7% O_2
16. Total TCDD & TCDF as TCDD equivalent	0.1399	0.1231	fg/Nm³ dry @ 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 7% O_2 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 #I-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 HCl 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 0 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 particulates, acid

[19] That is, wet scrubbing cools the flue gases to the water saleration 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 (116).

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 particulates, can suffer problems of corrosion and erosion problems and reentrainment of particulates, 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 HCl and sulfur dioxides in one dry scrubber system for a MSW incinerator were reported to be 90 and 70 percent, respectively (116). 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 HCl 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 (116). 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 (114). 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 MSW (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 MSW (heat recovery) chambers (41).

ered. Another strategy is to use dedicated incinerators for medical wastes at sites permitted for MSW 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—on-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 in 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 fixed 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 (116).

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