MUNICIPAL INCINERATOR ASH—TECHNICAL AND REGULATORY TRENDS

JOHN M. McNURNEY AND
EVIS C. COUPPIS
R. W. Beck and Associates
Denver, Colorado

RENA I. STEINZOR
Spiegel & McDiarmid
Washington, D. C.

ABSTRACT

The question of how to regulate disposal of residue ash from municipal incinerators is a national issue. The scope of the issue is characterized in an overview defining the magnitude of the problem and key technical and regulatory aspects. Technical aspects including factors that affect ash composition and measures potentially used for environmentally acceptable landfill disposal of ash are further discussed. Key regulatory concepts related to existing and proposed legislation are also analyzed. The authors conclude that the most environmentally appropriate method of regulation may result from a moderate position supporting specific design and siting requirements for ash disposal under Subtitle D of RCRA as opposed to disposal under Subtitle C as a hazardous waste or under Subtitle D without such specific requirements.

OVERVIEW

Both the Environmental Protection Agency (EPA) and the Congress are under heavy pressure to impose stringent controls on the land disposal of incinerator ash. As municipalities across the country are discovering with some bitterness, the recent trend toward incineration as the preferred solution to the garbage glut could soon be stymied by these new proposals. Uncertainty both about the hazards posed by ash and its regulatory future are making it harder than ever to site incinerator facilities.

The purpose of this paper is to review the technical information regarding ash hazards and methods of controlling such hazards. The paper will also examine existing guidelines and proposals pending to regulate such disposal, and suggest the prognosis for such changes.

Roughly 150 million tons of municipal solid waste are generated each year in America, about a ton for every man, woman and child. By the end of the century, this amount is expected to increase to as much as 290 million tons per year [1]. The vast majority of solid waste is placed in landfills, but many of these facilities are at or near their capacity limits. Siting new landfills has become increasingly difficult, as public opinion and economic pressure against landfills has mounted. Adverse public opinion has increased due to concerns about health and potential environmental impacts as well as aesthetics. Economic pressure on landfills has increased because suitable sites are limited in some parts of the country and because additional environmental safeguards are being required more often.

Faced with constantly increasing quantities of solid waste as well as diminishing land disposal capacity, cities have turned more and more to other solid waste resource recovery management alternatives as a solution to their garbage dilemma. Essentially, all resource recovery strategies include incineration of some or all of the waste stream to recover energy and reduce the volume of solid waste. Some 111 municipal incinerators in the United States burn over 6 million tons of solid waste annually, or approximately 5–6% of the total solid waste generated. EPA estimates that some 210 additional facilities are planned or under construction. EPA also predicts that by the mid-1990's, incineration could account for as much as 25% of the nation's municipal solid waste disposal at as many as 300 facilities [2].

There can be little question that, under some circumstances, incinerator ash—especially fly ash—can pose hazards to human health and the environment. The major cause of the hazardous characteristics exhibited by ash is the heavy metals which are present in municipal solid waste and concentrated in the ash by the burning process. Lead and cadmium are usually the metals exceeding the standards. Dioxin and furan compounds also usually are present. Human contact with unsafe amounts of such materials through pollution of drinking water, inhalation, or direct contact may cause cancer, birth defects, neurological disorders, and other chronic health effects. The question is what levels occur in residue ash and whether people will be exposed to them.

Over the past few months, the issue of how to regulate disposal of residue ash resulting from incineration of municipal solid waste has become a national issue. Regulatory requirements which may be instituted by Congress through new legislation or by EPA through rule making associated with existing laws could have far reaching effects on the potential for incineration as a solid waste management alternative. There are two types of technical issues that should be considered in revising regulatory requirements including the following: *(a)* characteristics of the variations in ash composition related to input waste, incinerator technology, and use of air pollution control devices; and *(b)* potential methods of environmentally acceptable land disposal of ash.

In an effort to promote stringent regulation of incinerator ash under Resource Conservation and Recovery Act (RCRA), the Environmental Defense Fund (EDF), a national group of environmental activists, recently began a campaign designed to force municipal incinerator operators to test their ash on a routine basis, and dispose of it as a hazardous waste when appropriate. This past spring, EDF wrote most operators of existing facilities letters putting them on "notice" that their ash might be "hazardous" under the law. The organization has threatened to bring lawsuits against incinerator owners and operators who do not test their ash under the citizens' suit provisions of RCRA [3]. If successful, EDF lawsuits could result in court orders and assessment of penalties against such owners and operators. Both the testing and the disposal methods sought by the group are costly, and could increase community concern about the safety of such facilities. (Note: Since this paper was drafted, EDF has sued two municipal incinerator owners.)

In a reaction to the EDF efforts, EPA announced that although incinerator ash is not listed as a hazardous waste, municipalities should not assume that residue ash is exempt from hazardous waste regulation. It is the legal obligation of facility operators to determine whether their waste streams are hazardous.

Meanwhile, on Capitol Hill, Congressman James J. Florio, a long-time activist on environmental issues and the father of the Superfund toxic waste cleanup program, has introduced legislation [4] designed to force EPA to come out with systematic new regulations concerning the disposal of ash residues on a tight statutory schedule. Congressman Florio's bills would mandate disposal of ash as a hazardous waste unless EPA developed treatment standards for such residues. The bills would require regular testing of fly ash, bottom ash, and any combination of such materials. (Note: Since this paper was drafted, parallel legislation has also been introduced in the Senate.)

The authors of this paper believe that unless new controls on municipal incinerator ash are carefully structured, Congress and EPA run the risk of driving municipal solid waste disposal from incineration to the even more environmentally undesirable alternative of using sometimes inadequately protected landfills. Environmentally acceptable disposal of residue ash in properly designed landfills using appropriate management techniques is available. Such design requirements as double liners, leachate collection systems, and landfill caps for residue ash monofills could be considered along with siting constraints as potential new requirements under Subtitle D of RCRA. This moderate position should be favored over conservative testing procedures to define hazardous wastes and restrictive prohibitions regarding mixing and treatment alternatives. The authors believe that Congress and EPA should seriously consider such reasonable suggestions because designation of incinerator ash as a hazardous waste would tax limited availability of hazardous waste facilities and would be prohibitively expensive in many cases.

REVIEW OF TECHNICAL ISSUES

There are two key technical issues concerning residue ash disposal as described briefly in the overview section. The first issue involves accurate characterizasection. The first issue involves accurate characterization of residue ash with respect to variations related to the input waste stream, the incinerator technology used, and the associated air pollution control devices. The second issue addresses the availability of practical methods of landfill disposal for residue ash in an environmentally acceptable manner.

Ash Characteristics

There are relatively few data available to describe resource recovery facility residue ash. Such data are frequently regarded by manufacturers and operators as proprietary information. Futhermore, the ash quality can be expected to vary greatly depending on such factors as the waste composition, incinerator technology, and scrubber type.

Residue ash is known to include several components which affect its potential impact on the environment. Those components include water soluble salts, metals, organics, acidic compounds, and buffers derived from combustion by-products and scrubber sorbent material. Bottom ash may be generally characterized as relatively large particles with a high pH in the range of 10 pH units. On the other hand, fly ash generally contains small particles with more available potential pollutants then bottom ash including complex organic compounds. Fly ash also usually has a pH which is neutral or slightly acidic in systems without scrubbers and basic (pH of 11–12) in systems with dry scrubbers. Thus, fly ash has a greater potential to adversely impact the environment than bottom ash because it contains higher concentrations of some key contaminants and they are generally more available to leaching due to the small particle size of such ash. The variability of components of incinerator ash are summarized in Table 1 based on data from the University of Massachusetts [5] and Environment Canada [6].

The primary pathway for human exposure to residue ash components is through ground water contaminated by leachate from a residue ash landfill. At some municipal waste landfills, other pathways such as surface runoff from ash disposal areas to surface waters can be significant. However, proper ash handling and landfill operation can minimize the potential for direct contact, air emissions of fugitive dust, or contamination of surface runoff. The available data indicate that total dissolved solids, lead, and cadmium are the pollutants of concern in residue ash leachate. Those pollutants have the following combined characteristics: *(a)* they occur in high concentrations in the ash; *(b)* a large portion of each of the components is leachable if the leaching media is acidic; and *(c)* they can be relatively toxic. Table 2 summarizes data from Environment Canada [6] which indicates the relative availability of some metals commonly found in residue ash.

TABLE 1 EXPECTED RANGE OF SELECTED COMPONENTS FOR VARIOUS TYPES OF ASH FROM RESOURCE RECOVERY FACILITIES

Ash Constituent	Approximate Minimum	Approximate Maximum
pH	6.6	12.4
TDS (mg/l)	3,000	20,000
Cadmium (ug/g)	5	350
Chromium (ug/g)	200	1,100
Copper (ug/g)	1	750
Nickel (ug/g)	20	2,000
Lead (ug/g)	400	8,000
Zinc (ug/g)	800	19,000
Boron (ug/g)	10	5,600
Cobalt (ug/g)	25	1,700
Total Sulfur (ug/g)	6,900	30,300
Polychlorinated dibenzo-p-dioxins (ng/g)	5	700
Polychlorinated dibenzofurans (ng/g)	5	400
Polynuclear aromatic hydrocarbons (ng/g)	20	5,000
Chlorobenzenes (ng/g)	100	4,000
Chlorophenols (ng/g)	50	7,000

Data sources: References 5 and 6.

The leachate from residue ash landfills generally can be expected to follow certain trends as demonstrated by leaching studies conducted at the University of Massachusetts [5]. Total dissolved solids concentrations in the leachate likely will be high initially but decrease substantially during the first few years after placement and continue to decrease at a slower rate as time goes on. Metals concentrations in the leachate will continue to be low as long as high pH is maintained in the leach water in the landfill. Low metals concentrations will occur as long as the buffer capacity of the ash continues to neutralize the acidity of the incoming rainfall. However, some metals (especially lead and cadmium) will remain available to be leached if an acid leaching media was to be introduced. Dioxin and furan compounds in the ash would be expected to remain in the landfill because their solubility in water is extremely low [7].

It is clear that reducing the amount of metals in municipal solid waste will reduce the concentrations of those compounds in the resulting residue ash. The authors are not aware of any published data that quantify that relationship. However, it is reasonable to assume that contaminant concentrations may be favorably affected by recycling programs, waste separation, and future manufacturing standards that limit the use of compounds such as lead and cadmium.

Incineration technology can be expected to affect the composition of ash as a result of variations in combustion efficiency. How well the waste is burned can be expected to affect the chemical composition and, to

TABLE 2 PERCENTAGE OF MATERIAL POTENTIALLY REMOVED FROM FLY ASH USING VARIOUS TYPES OF LEACHING MEDIA

Ash Constituent	Weak (Water)	Aggressive (Dilute Acid)	Severe (Strong Acid)
Cadmium	0	80	95
Chromium	0	10	20
Copper	2	15	40
Nickel	0	15	40
Lead	5	60	85
Zinc	0	55	70
Boron	2	40	70
Cobalt	0	30	30
Total Sulfur	-	-	-

Source: Reference 6.

TABLE 3 CALCULATED EFFECTS (IN PERCENT BY WEIGHT) OF A DRY SCRUBBER ON ASH FROM INCINERATORS

Large Scale Plant :	Composition of Fly Ash		Composition of Fly & Bottom Ash Combined	
	SR=2*	SR=3	SR=2	SR=3
Ash	66	58	95	93
Reaction Products	18	16	3	3
Unreacted Lime	16	26	2	4
Modular Plant :	**Composition of Fly Ash**		**Composition of Fly & Bottom Ash Combined**	
	SR=2	SR=3	SR=2	SR=3
Ash	28	22	95	93
Reaction Products	38	30	3	3
Unreacted Lime	34	48	2	4

* SR = Stoichiometric ratio compares the relative amount of lime actually injected to that theoretically required to react with all acid gases.

some extent, the size distribution of ash particles. The nature of this type of variation needs to be investigated further.

Two types of air pollution control devices are used on incinerator facilities. Particulate control devices, including electrostatic precipitators and baghouses, affect the quantity and size distribution of fly ash collected. More efficient equipment increases the potential hazard of ash by increasing the amount of contaminants included in the ash and by selectively removing smaller particles from the flue gas. On the other hand, acid gas scrubbers used in conjunction with a particulate removal system can favorably affect the composition of fly ash from an environmental perspective.

The most dramatic and environmentally advantageous effects on ash composition can be expected to result from the use of dry scrubbers and associated efficient particulate collection. Such devices are used primarily to control acid gas emissions from incinerators. Since large plants (as well as many small plants) that will be constructed in the future are likely to be equipped with dry scrubbers, the effect of the dry scrubber technology on ash characteristics and leachability must be considered.

The primary types of dry scrubbers employed on waste-to-energy plants include the spray-dryer and a variety of dry injection systems. The common tie among all of these different types of acid gas removal systems is that hydrated lime (either in slurry or dry hydrated form) is added to the flue gas to react with the acid gases. An amount of lime in excess to what is theoretically required to react with the acid gases in the flue gas is added to the system. The characteristics of the fly ash collected at the particulate collection device are changed from those characteristics encountered at plants not equipped with an acid gas scrubber. The effect of the dry scrubber on ash composition is estimated in Table 3.

As can be seen from the estimates in Table 3, the dry scrubber has a significant effect on the composition of the fly ash. The reaction products and unreacted lime account for about 40–80% of the total amount of material collected at the particulate collection device depending on the plant type and the stoichiometric ratio of lime injected. The composition of the combined fly ash and bottom ash is affected to a lesser extent although reaction products and unreacted lime make up approximately 5–10% of the total ash by weight.

The key characteristics that must be evaluated with respect to the effect of the dry scrubber on ash characteristics include:

(a) How will the increased amount of lime affect the leachability of metals? Generally, an increased pH inhibits leachability of most metals. Whether the degree of inhibition will be pronounced enough to allow the ash to consistently pass the EPA test procedures needs to be addressed.

(b) How will the affect of the dry scrubber on particle size distribution affect leachability? Generally, larger particles and coating of fly ash particles, factors that generally decrease leachability, can be expected with dry scrubbing.

(c) Will the expected increased collection efficiency of trace metals in the dry scrubber/particulate collection system affect ash metals concentration? The increased collection of metals is likely to be offset by the excess lime and scrubber products also collected.

Landfill Disposal

The environmental risks of landfill disposal of residue ash are predictable and manageable. The key concerns are selection of an appropriate site and utilization of proper design criteria and management techniques.

Site conditions can be a major factor in assessing landfilling as an alternative for residue ash disposal. The meteorology, geology, soil characteristics, and hydrogeology of a location may significantly affect the function of various measures designed to control potential impacts from a landfill. In addition, these factors also will determine pathways for human or environmental exposure and may naturally mitigate adverse impacts. The potential of control technologies cannot be fully evaluated in most cases until a thorough characterization of local and regional conditions has been completed. Once the site conditions have been defined, appropriate pollution control measures can be evaluated.

An evaluation of pollution control measures would involve an examination of the applicability and expected effectiveness of various design, operating, and closure alternatives in light of the local conditions and issues existing at potential sites. The items evaluated under this type of effort usually would include the following:

(a) Environmental control systems and support facilities such as double liners, leachate collection systems, landfill caps, and surface water management systems.

(b) Leachate treatment and disposal options.

(c) Site monitoring.

(d) Methods for mitigation of potential environmental impacts.

(e) Post closure operation and maintenance activities and financial support.

(f) Site end use.

The key step in the process would be to select and coordinate a strategy for managing the risks to the environment of a residue ash landfill. There are liner options and leachate collection and treatment systems that are proven over many years use to be effective at virtually eliminating local impacts of leachate. While none of the current protection options is capable of lasting forever, the objective of such devices is to control the situation when the risks to the environment from leachate are greatest. After many years when the potential of failure of the landfill liners and leachate collection and treatment system have increased, it is expected that the potential for environmental impact will have declined due to physical and chemical changes in the residue ash and the landfill.

Those changes are expected to be related to the changing characteristics of the residue ash, closure of the landfill, the design of the landfill cap, and post closure land use. Residue ash is largely inert and organic content is low; therefore, the decomposition activity typical of a municipal solid waste landfill will not occur unless the ash is codisposed with other wastes. Soluble salts will decrease over time leaving less material to be leached [5]. At the same time, the finished landfill will be capped to minimize infiltration of rainwater. Post closure land use such as establishment of natural plant communities on the cap material will promote greater utilization of water in surface soils further reducing infiltration. In addition, proper land management will result in well buffered surface soil to neutralize the acid nature of precipitation. The ultimate objective for such a landfill should be to minimize leaching of metals and dissolved solids into the ground under the site.

REGULATORY AND LEGAL TRENDS

As discussed in the Overview section of this paper, the major controversy under current law regarding the disposal of incinerator ash is whether and when operators of such facilities must test ash residues to determine if they are hazardous. RCRA takes two approaches to identifying what wastes are in fact hazardous: *(a)* it lists several hundred such substances; and *(b)* it requires that generators of wastes that are not listed must determine on their own if their wastes are hazardous by testing the wastes in accordance with EPA protocols [8]. If the wastes fail these tests, they must be disposed of in a RCRA Subtitle C hazardous waste disposal facility. Wastes that pass the tests can be taken to a Subtitle D municipal landfill where ordinary garbage is dumped. Severe civil and even criminal penalties apply to violations of these requirements.

Incinerator ash is not listed as a hazardous waste. But depending on the circumstances, it may fail the Extraction Procedure Toxicity Test ("EP Toxicity Test") and therefore be characterized as a hazardous waste. The law is very tricky in this gray area of testing wastes. Although EPA does not have a regulation on the books which affirmatively requires that all incinerator ash be routinely tested, the Agency has announced that:

> "[O]perators of municipal incinerators should not assume that their wastes are automatically exempt from federal and state hazardous waste regulations . . . EPA's position has been and remains that fly ash and bottom ash which are determined to be hazardous must be managed as hazardous wastes. It is

the legal obligation of facility operators to determine whether their waste streams are hazardous wastes." [9]

EPA has therefore come as close as it can to stating an affirmative testing obligation. EPA's position has only exacerbated the quandary of most municipal incinerator operators, many of whom may not be testing in fear that the ash would turn out to be "hazardous" under RCRA. Limited hazardous waste landfill disposal capacity could make the price of incineration prohibitive and shut the incinerator down.

Beyond this guidance from the Agency, if an owner or operator does not test and it later turns out that the ash was hazardous and was disposed of improperly, the owner and incinerator facility can be subject to severe penalties, whether or not the original decision concerning testing was made in good faith. The owner and operator can also be asked to pay the costs of cleaning up such wastes, which can run into millions of dollars. In short, it is risky to avoid knowledge of the true character of the ash an incinerator produces.

EPA has indicated no current plans to propose new regulations concerning ash disposal. The Agency is in the process of writing guidelines concerning how to sample and test the ash; these guidelines are expected to state that the ash residues from incinerators which process only household waste are exempt from regulation as a hazardous waste [10]. Beyond issuing this guidance, EPA plans to continue to test samples from incinerators across the country and to research alternative technologies to decrease ash hazards [11].

The legislation introduced by Congressman Florio would resolve any questions about testing by requiring all incinerator owners or operators to separately test bottom ash and fly ash, and then also test any combination of bottom and fly ash that they generate [4]. The legislation would further require that the test results be submitted to EPA or an authorized state authority on a quarterly basis. EPA would be charged with developing regulations concerning the frequency and nature of such testing requirements.

Although the bill would not prohibit mixing of fly ash and bottom ash, its requirement that separate test results be reported could increase the pressure on incinerator operators to stop mixing. Further, environmentalists are urging Congressman Florio to change his bill to affirmatively prohibit mixing. As explained above, any prohibition on mixing could be extremely significant because fly ash is more likely to be toxic than bottom ash, and many operators mix the two types of ash in an effort to diminish this toxicity.

As for determining the "hazard" posed by incinerator ash, and therefore the requirements that will apply to its disposal, the Florio bill would mandate that EPA develop criteria for ash within 12 months after enactment of the legislation, after considering a variety of factors. Such factors include whether the ash because of its quantity, concentration, or physical, chemical or infectious characteristics may cause or contribute to increases in mortality, incapacitating illnesses, or pose a substantial, present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of. These criteria are significant in several aspects.

First, the agency must consider not only demonstrable current effects, but potential future effects. It must study ash from "cradle to grave" and beyond. It must consider all potential pathways of human or environmental exposure including inhalation and ingestion. And it must consider such problems as incorporation of ash toxics into the food chain, ingestion of potable water or fish contaminated by surface runoff from ash, leaching and percolation of ash contaminants into groundwater or surface water, ingestion or inhalation of soil particles contaminated by ash, and dermal contact with such ash.

As for disposal, the Florio bill would require that ash which flunks the tests developed by EPA must be disposed of at a RCRA Subtitle C facility. Alternatively, the ash may be treated in accordance with new standards to be promulgated by the Agency until it no longer flunks the test. It could then be disposed of at a normal municipal landfill.

The prognosis for enactment of legislation in the ash area during the 100th Congress is not clear. Advocates of such legislation also wish to pass new requirements controlling air emissions from municipal incinerators and ultimately would want to tie new incinerator ash and air emissions requirements together in one legislative package. However, Congress is currently embroiled in a legislative gridlock regarding how to reauthorize the entire Clean Air Act. Therefore, unless municipal incinerator legislation can be separated out from this larger package, and moved separately, chances of final passage before 1989 are remote.

CONCLUSION

The lack of comprehensive federal regulatory guidance on residue ash is already affecting resource recovery projects. Municipal and regional authorities are questioning the economic feasibility of projects partially because of the uncertainty regarding ash disposal requirements. The prospect of regulating ash under Subtitle C of RCRA could substantially impede development of such projects because of the potentially high costs of treating or disposing of even the fly ash component of a large project. This result will necessarily prolong continued landfilling of municipal solid waste and the potential problems of such disposal. The potential problems can be put in perspective by considering that approximately 20% of the sites now included on the Superfund National Priorities List of the nation's worst facilities are municipal solid waste landfills.

The legislative process now under way could result in very conservative residue ash testing protocols and tough restrictions on ash mixing and treatment. The result of such regulations could cause most residue ash to be disposed of in hazardous waste landfills. Disposal of remaining ash would be permitted in often inadequately protected municipal waste landfills. Disposal in a hazardous waste landfill would be very costly and could result in large volumes of marginally hazardous ash being combined with acutely hazardous material, using up the limited space in such facilities. Disposal in a municipal waste landfill could result in co-disposal with municipal waste in a landfill with only marginally effective pollution controls and monitoring. In many respects, both alternatives fail the primary goal of protection of the environment.

Regardless of the costs involved, it seems impractical to mix large volumes of residue ash with significantly more hazardous material in a hazardous waste landfill. The large volume of ash to be landfilled would utilize limited hazardous waste landfill capacity that would be better dedicated to more problematic material. Furthermore, other demands on hazardous waste disposal facilities can be expected to increase dramatically over the next several years for two other reasons. First, 1984 amendments to RCRA will result in reclassifying large amounts of waste as "hazardous," including wastes produced by so-called "small quantity generators" [12]. Second, in 1986, Superfund was reauthorized at funding level of $8.5 billion for the period of 1986 through 1991, which will generate significant new quantities of hazardous wastes removed from abandoned dumps during the cleanup effort [13]. To compound these problems, EPA's slow and unpredictable permitting process under RCRA Subtitle C has deterred many from entering the market for such facilities.

It also seems inappropriate to allow residue ash that marginally passes the toxicity tests to be mixed with municipal solid wastes in Subtitle D landfills. Many of these facilities consist of unlined landfills established with limited siting constraints and operated with minimal monitoring. Codisposal of residue ash and municipal solid waste under these conditions may be environmentally irresponsible in that human exposure through ground water pollution or direct contact with ash components may occur.

The authors of this paper believe that new controls on municipal incinerator ash should be carefully structured by Congress and EPA. Environmentally acceptable disposal of residue ash in properly designed landfills using appropriate management techniques is practicable. Such design requirements as double liners, leachate collection systems, and landfill caps as well as siting restrictions could be considered as potential new requirements under Subtitle D of RCRA specifically for residue ash monofills. This moderate position is favored over conservative testing procedures to identify hazardous wastes and restrictive prohibitions regarding mixing and treatment alternatives. The authors believe that Congress and EPA should seriously consider defining conditions for ash monofills because designation of incinerator ash as a hazardous waste would promote continued disposal of solid waste in municipal landfills which already pose a significant hazard to human health and the environment.

REFERENCES

[1] Florio, James J. Statement before the Subcommittee on Health and the Environment of the Committee on Energy and Commerce, U.S. House of Representatives, July 2, 1987, at pg. 1

[2] U.S. Environmental Protection Agency. "Municipal Waste Combustion Study: Report to Congress", prepared by the Radian Corporation. June 1987, vi–viii. Springfield, Virginia: U.S. Department of Commerce, National Technical Information Service.

[3] *Resource Conservation and Recovery Act* is a title of the *Solid Waste Disposal Act,* 42 U.S.C. 6901 et seq.

[4] H.R. 2517, May 27, 1987. Congressman Florio has also introduced related legislation to control air emissions from municipal incinerators: H.R. 2516, May 27, 1987, and H.R. 2767, June 25, 1987.

[5] Mika, J. S., and Feder, W. A. "RESCO Incinerator Residue Research Program — Results Evaluations and Recommendations — Final Report." October 1985. Waltham, Massachusetts: University of Massachusetts, Suburban Experiment Station.

[6] Sawell, S. E., Bridle, T. R. and Constable, T. W. "Assessment of Ash Contaminant Leachability. NITEP Phase II — Testing of the FLAKT Air Pollution Control Technology at the Quebec City Municipal Energy from Waste Facility." December 1986, Document IP-70. Burlington, Ontario, Canada. Environment Canada.

[7] Marple, L., Brunk, R., and Throop, L. "Water Solubility of 2, 3, 7, 8 Tetrachlorodibenzo-p-dioxin." *Environmental Science and Technology* 20 (no. 2 1986).

[8] *Resource Conservation and Recovery Act,* 42 U.S.C. 6921.

[9] "EPA Statement on Environmental Defense Fund Press Release." Issued by the EPA Office of Public Affairs (A-107), March 12, 1987, 1.

[10] "Draft Sampling and Analysis of Municipal Refuse Incineration Ash." Office of Solid Waste, U.S. Environmental Protection Agency, July 1987.

[11] Statement of J. Winston Porter, Assistant Administrator of the Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, before the Subcommittee on Transportation and Hazardous Materials of the Committee on Energy and Commerce, U.S. House of Representatives, March 19, 1987, 3–5.

[12] Hazardous and Solid Waste Amendments of 1984, 42 U.S.C. 6901 et seq.

[13] *Superfund Amendments and Reauthorization Act of 1986*, 42 U.S.C. 9601 et seq.