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# Regulating Municipal Solid Waste Incinerators Under the Clean Air Act: History, Technology and Risks

Arnold W. Reitze, Jr.

Andrew N. Davis

# REGULATING MUNICIPAL SOLID WASTE INCINERATORS UNDER THE CLEAN AIR ACT: HISTORY, TECHNOLOGY AND RISKS†

*Arnold W. Reitze, Jr.**
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* Elyce Zenoff Research Professor of Law and Director of the LL.M. program in environmental law at The George Washington University. J.D. 1962, Rutgers University; B.A. 1960, Fairleigh Dickinson University; M.P.H. 1985, The Johns Hopkins University.

** Associate, Brown, Rudnick, Freed & Gesmer, P.C. Hartford, CT. J.D. 1990, The George Washington University; B.S. 1981, Trinity College (Connecticut), M.S. 1983, Ph.D. 1987, The University of Massachusetts at Amherst.

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## I. INTRODUCTION

The problems associated with managing municipal solid waste (MSW)[1] in the United States are both environmental and economic. Where to put the ever-increasing garbage has become an important issue at all governmental levels. It is estimated that the total MSW generated in the United States in 1990 was nearly 180 million tons, and that amount is expected to increase ten percent by the year 2000.[2] However, most statistics concerning solid waste seem to be crude guesses and actual amounts may be much higher because the United States Environmental Protection Agency's (EPA) often-used numbers are based on dry waste.[3] Although most of the MSW increase is due to population growth, consumption increase is also important as each person seems to be generating more waste on average.[4]

Today, a general consensus has developed among waste management professionals that a hierarchy of waste management options exists that ranges from most to least environmentally protective.[5] This hierarchy includes:

1. waste reduction so that fewer harmful residuals are produced, including process changes and raw material substitutions;
2. waste recycling, including resource recovery;
3. physical, chemical, and biological treatment that reduces volume and/or toxicity;

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[1] MSW is defined as "solid waste generated at residences, commercial establishments (e.g., offices, retail shops, and restaurants), and institutions (e.g., hospitals and schools)." U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, FACING AMERICA'S TRASH: WHAT NEXT FOR MUNICIPAL SOLID WASTE 4 (1989) [hereinafter OTA Report]. "[The] waste may be categorized as materials (e.g., glass and paper) or products (e.g., appliances, containers and tires)." *Id.*

Under the Resource Conservation and Recovery Act (RCRA), solid waste is more broadly defined as: "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities . . . " 42 U.S.C. § 6903 (1988).

[2] *EPA Strengthens Air Emissions Standards for Municipal Waste Incinerators*, 41 J. AIR WASTE MGMT. ASS'N 259 (1991).

[3] William F. Pedersen, Jr., *The Future of Federal Solid Waste Regulation*, 16 COLUM. J. ENVTL. L. 109, 113 n.12 (1991).

[4] OTA Report, *supra* note 1, at 4. The model estimated that each person in the United States generated 3.6 pounds of garbage per day in 1986, and this figure is projected to grow to 3.9 pounds per day by 2000. *Id.*

4. incineration; and,
5. solidification and/or stabilization followed by land disposal.[6]

This hierarchy reflects the concern for both hazardous and non-hazardous waste disposal. Environmentalists often argue that incineration should not be given a higher position in the hierarchy than use of landfills. Moreover, they often oppose both approaches because of their perceived adverse effects on recycling efforts.[7] In 1990, EPA claimed its "Agenda for Action" promoted a three-tiered hierarchy—source reduction first, recycling second, and incineration/landfilling third.[8] This indicates an EPA tilt against incineration, a significant departure from its 1988 position that seemed to favor incineration over landfills.[9]

By 1989, eighty percent of the MSW was being sent to 6,000 landfills, but half of these sites were expected to close within five years.[10] As a result of ever-increasing amounts of solid waste, declining landfill capacity, stricter legal regulations, and rising costs, there is renewed interest in MSW incineration. The Resource Conservation and Recovery Act (RCRA) Subtitle D regulations for MSW landfills require such landfills that receive wastes after October 9, 1993 (or April 9, 1994, for certain small MSW landfills) to comply with strict provisions that are both technically and economically onerous.[11] The

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[5] *See* Wolf, *Source Reduction and the Waste Management Hierarchy*, 38 JAPCA 681 (1988).

[6] The hierarchy does not include ocean dumping that has been used in the past because that option is now unlawful. *See, e.g., EPA Signs First Cooperative Agreement to Enforce Ocean Dumping Ban*, INSIDE EPA, June 29, 1990, at 11.

[7] *Recommendations for EPA's RCRA Program*, ENVTL. POL'Y ALERT—SPECIAL REPORT, Dec. 28, 1988 at 6.

[8] *EPA to Clarify Incinerators on Par with Landfills in Waste Strategy Update*, INSIDE EPA, Feb. 23, 1990, at 6.

[9] *In Significant Policy Change, EPA Says Landfills on Par with Incinerators*, INSIDE EPA, Jan. 5, 1990, at 1. EPA, however, does not speak with one voice on this issue. A 1991 EPA draft report on scrap tire recycling recommended the use of tires as furnace fuel, only to be opposed by EPA's Office of Policy Planning & Evaluation. *EPA Policy Staff Criticize Draft Scrap Tire Report for Emphasizing Incineration*, INSIDE EPA, Mar. 22, 1991, at 12.

[10] Standards of Performance for New Stationary Sources: Municipal Waste Combustors, 54 Fed. Reg. 52,209, 52,251 (EPA 1989) (to be codified at 40 C.F.R. §§ 51, 52, 60) (proposed Dec. 20, 1989).

[11] *See* Solid Waste Disposal Facility Criteria, 56 Fed. Reg. 50,978 (EPA 1991) (to be codified at 40 C.F.R. §§ 257, 258); *see also infra* notes 54–77 and accompanying text. On July 28, 1993, the EPA proposed regulations that delay the effective date of the Subtitle D regulations for six months (to Apr. 9, 1994) for certain small landfills and delays for one year (to Oct. 9, 1994) the effective date of the financial assurance requirements for all landfills. Solid Waste Disposal Facility Criteria; Delay of Effective Date, 58 Fed. Reg. 40,568 (EPA 1993)(to be codified at 40 C.F.R. § 258) (proposed July 28, 1993). To qualify for the extension, a landfill must: (1) receive 100 tons per day or less; (2) be located in a state that has submitted an application for program approval to EPA before Oct. 9, 1993 or is located on tribal lands; and (3) is not currently on the

costs of compliance will make incineration a more attractive option. Currently, about fourteen percent of all MSW is incinerated (mostly with energy recovery), thirteen percent is recycled and nearly everything remaining is sent to landfills.[12] With new regulations for MSW incinerators and the beginning of implementation of the Clean Air Act Amendments (CAA Amendments) of 1990, it is time to reexamine the role of incineration in MSW management.

This article first describes the current status of MSW management and disposal in the United States. Second, the history, technology, legal regulation, health effects and environmental risks of MSW incineration are addressed. Finally, the article assesses the viability and necessity of MSW incineration within the confines of the hierarchy of currently-available waste management options. The United States must, with some urgency, develop and utilize methods that reduce, recycle, treat, and destroy our growing inventory of MSW. Utilized in conjunction with source reduction and recycling, MSW incineration has the potential to be a viable and needed part of any rational solid waste management program.

## II. The Municipal Solid Waste Problem in the United States

### *A. Municipal Solid Waste Management Options—The Hierarchy*

#### 1. Waste Prevention/Minimization (Source Reduction)

The best way to deal with the problems of declining landfill capacity, consumption of virgin materials, and the release to the environment of hazardous materials contained in waste is to prevent the generation of MSW. Significant progress in waste prevention will only be realized when manufacturers change the design and packaging of products to avoid either generation of wastes during production and marketing and/or to overcome disposal problems at the end of the product's useful life. Waste prevention will also succeed and have a significant impact on MSW reduction when consumers change both their con-

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Superfund National Priorities List (NPL). *Id.* at 40,570–73. On October 1, 1993, EPA issued the final rule delaying the general date for compliance with the Subtitle D criteria until April 9, 1994 for certain small landfills and delayed the effective date of Subpart G, Financial Assurance, until April 9, 1995 for all MSW landfills. Solid Waste Disposal Criteria; Delay of Compliance and Effective Dates, 58 Fed. Reg. 51,536 (EPA 1993) (final rule Oct. 1, 1993).

[12] *EPA Strengthens Air Emission Standards for Municipal Waste Incinerators*, 41 J. Air Waste Mgmt. Ass'n 259 (1991).

sumption habits as well as their manner of disposing of what they purchase.[13] Waste reduction efforts can be aimed at reducing quantities and/or toxicities of waste. It can be as simple as reusing an item rather than replacing it, or producing quality products with longer useful lives. To date, even though the EPA must collect and disseminate information on source reduction under the 1990 Pollution Prevention Act, no significant national movement toward waste reduction has arisen.[14] Waste generated in the United States increases by about one percent a year with about seventy percent of this increase created by population growth.[15] Concomitantly, our ability to manage MSW is declining.

Reducing the amount of MSW generated will be difficult. Today, packaging accounts for thirty percent of the volume of MSW, with plastics and paper accounting for half the volume of waste going to landfills.[16] The weight of packaging wastes has been declining as plastics and foam products replace glass and metal, but the total volume of packaging has remained essentially constant.[17] Despite the negative aspects of packaging, it is important to note that it serves important functions. These include decreasing spoilage and preventing pilferage or tampering. Such functions could be compromised by stringent environmental regulation.[18]

Some waste reduction measures, however, have minimal down-side risks. The manufacture of some products for which there is minimal need, such as direct mail, oversized newspapers, and some single-use throw away products (e.g., styrofoam cups), might be discouraged if producers are forced to internalize the costs of proper disposal. Also, with approximately twenty percent of MSW comprised of yard wastes, increased home composting could be a useful way to reduce waste.[19] However, whenever the government involves itself in regulating the details of the economy, the resulting impact on employment, tax revenues, and even the environment, is often unpredictable.

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[13] Consumers have little incentive to avoid creating solid waste since the cost of disposal is usually financed as part of property taxes. Thomas R. Mounteer, *How To Pay For Cleaning Up Co-Disposal Sites: Enlarging the Scope of the Debate*, 23 Env't Rep. (BNA) No. 23, at 1520, 1524 (Oct. 2, 1992).

[14] 42 U.S.C. §§ 13101–13109 (Supp. 1991).

[15] OTA Report, *supra* note 1, at 74–75.

[16] *Municipal Solid Waste Characterization Study Update Finds Landfilling Down, Recycling Up*, 40 J. Air Waste Mgmt. Ass'n 1088 (1990).

[17] Environmental Quality, The Eighteenth and Nineteenth Annual Report of the Council on Environmental Quality 1987–1988 6 (1989).

[18] OTA Report, *supra* note 1, at 112.

[19] OTA Report, *supra* note 1, at 80 and 184–90.

Moreover, by factoring in the amounts of energy and raw materials that are used and the waste that is generated in the manufacture of "environmentally compatible" products, it is apparent that focusing on waste disposal (such as the production of degradable plastics) may not achieve much environmental improvement.

A major problem with MSW is that neither the manufacturer nor the purchaser bear the disposal cost associated with the toxic materials found in these wastes. For example, three toxic heavy metals—cadmium, lead, and mercury—are pervasively used in consumer products.[20] Cadmium is primarily used for coating and plating; it is also found in batteries and in plastics.[21] Mercury is used in batteries and electrical devices.[22] Lead is primarily used for automobile batteries, but it is also used in electronic products and in plastics.[23] Toxic organic chemicals are found in substances such as inks, particle board, glue, and cleaners.[24] More than one hundred toxic substances that are classified as hazardous under RCRA are found in common household products.[25] Only rarely are substances banned in consumer products. One example of a ban was the limited chlorofluorocarbon (CFC) ban imposed by the Food and Drug Administration in 1978.[26] Other than this, few direct controls on hazardous substances in potential wastes exist. Concern for tort liability, employee protection, and the need to meet Clean Air Act (CAA) emission limitations during manufacturing processes are examples of indirect pressures to reduce the amount of toxic substances in the waste stream.

A number of state statutes attempt to limit hazardous waste generation. For example, California's "Proposition 65" requires manufacturers to prove that substances used in products are not toxic.[27] Effective labeling or other communication concerning the toxicity of products would assist consumers who desire to purchase more environmentally benign products. Few laws exist to mandate these ac-

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[20] ENVIRONMENTAL QUALITY, THE EIGHTEENTH AND NINETEENTH ANNUAL REPORT OF THE COUNCIL ON ENVIRONMENTAL QUALITY 1987–1988 21 (1989).

[21] OTA Report, *supra* note 1, at 102.

[22] *Id.*

[23] *Id.*

[24] *Id.*

[25] *Id.* at 103. *See* Lists of Hazardous Wastes, 40 C.F.R. §§ 261.31–261.33 (1992).

[26] 43 Fed. Reg. 11,301, 11,318 (1978). CFCs were regulated because of their adverse impact on the upper atmosphere ozone layer. They are not hazardous.

[27] Proposition 65, The Safe Drinking Water and Toxic Enforcement Act of 1986. CAL. HEALTH & SAFETY CODE §§ 25249.5–25249.13 (West Supp. 1992).

tions, however. Instead, laws often work to create barriers to pollution prevention.[28]

Reducing quantities of MSW will be difficult. Packaging wastes, which make up thirty percent of MSW by weight, are often singled out as a prime target for waste reduction efforts. Market forces encourage manufacturers to minimize packaging wastes, at least by weight, because of shipping and handling costs. Legal efforts to force reductions in packaging wastes can result in products with higher manufacturing environmental problems, increased product waste (e.g., food spoilage), or other problems. Moreover, the wastes generated from "ready-to-eat" and "fast-food" packaging are a part of the U.S. consumers' entrenched life-style. Changes in solid waste generation require consumer behavior modification that will not come easily.[29] At this time, although EPA is working to disseminate ideas and structure incentives for waste minimization, we have no meaningful legal regime to reduce the generation of MSW.[30] Ultimately, the major push in this direction will come from the effects that increasing cost and disposal difficulties have on the economics of the manufacturing process.

## 2. Recycling

Recycling consists of: (1) collecting secondary materials; (2) preparing the materials for market; and (3) manufacturing new products from the recycled material.[31] The amount of recycling in the United

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[28] R. Lee Byers, *Regulatory Barriers to Pollution Prevention: A Position Paper of the Implementation Council of the American Institute for Pollution Prevention*, 41 J. AIR WASTE MGMT. ASS'N 418 (1991).

[29] OTA Report, *supra* note 1, at 97–131.

[30] *See, e.g.*, Blueprint for National Pollution Prevention Strategy, 56 Fed. Reg. 7849 (EPA 1991); *see also EPA Officials Pick Two Dozen Rules to Emphasize Pollution Prevention*, INSIDE EPA, Dec. 20, 1991, at 5. For toxic pollutants, the Pollution Prevention Act of 1990, 42 U.S.C. §§ 13101–13109 (1988 & Supp. III 1991), mandates the inclusion of information concerning source reduction and recycling for every toxic chemical required to be reported in the annual toxic chemical release form required by § 313 of the Emergency Planning And Community Right-To-Know Act (EPCRA) of 1986. 42 U.S.C. § 11023 (1988).

EPA has developed a program called the Industrial Toxics Project, or "33/50" initiative, based on the Pollution Prevention Act of 1990, to reduce releases of 17 chemicals by 33 percent by the end of 1992 and by 50 percent by the end of 1995 from the level of 1988 releases. Richard H. Robinson, *EPA's New Strategy for Pollution Prevention: What Does This Voluntary Program Offer Industry?* 22 Env't Rep. (BNA) No. 4, at 241 (May 24, 1991). *But see* Pamela A. D'Angelo, *Reilly's Corporate Volunteerism Campaign Marred By Skepticism*, 22 Env't Rep. (BNA) No. 49, at 2682 (Apr. 3, 1992) (reporting problems in achieving the 33/50 initiative's goals).

[31] Recycling has not been effectively defined under RCRA. This has led to claims of sham

States is frequently estimated at ten percent.[32] This is a crude estimate, though, and it varies greatly depending on the way in which MSW is defined. MSW is typically considered to include residential, commercial, and industrial waste.[33] But, construction demolition waste (i.e., bulky waste), for example, may or may not be included in the reported figures. There is also some question as to what is included in the concept of recycling: is waste that is produced during an intermediate stage of processing, and then returned to basic production, considered recycled waste? Regardless of how waste recycling statistics are developed, there is little doubt that U.S. recycling efforts are low in comparison with countries such as Japan.[34]

Recycling efforts are on the rise in the United States. The use of recycled glass, known as "cullet" in the glass manufacturing industry, increased from 24,000 tons a year in 1970 to more than one million tons in 1987.[35] Paper and paperboard recycling has increased to 28.5 percent or 22.6 percent, with the higher number including pre-consumer waste.[36] Aluminum has one of the highest rates of recycling—about forty-three percent says the Office of Technology Assessment (OTA) and more than fifty percent according to the National Solid Waste Management Association (NSWMA).[37] Municipal and business waste recycling efforts are helping to increase the recycling of ferrous metals, plastics, and yard wastes, although the data may lack reliability.[38]

MSW can be collected as mixed waste, or, to facilitate the recycling

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recycling being used to avoid environmental regulation. *See EPA Blasted for Lax Civil Enforcement During Marine Shale Criminal Investigation*, 20 Env't Rep. (BNA) No. 22, at 959 (Sept. 29, 1989); *Marine Shale—Company Thwarts Potential Liability by Purchasing Property*, ENVTL. POL'Y ALERT, Oct. 2, 1991, at 26. Sham recycling should be reduced or eliminated by the regulations controlling hazardous waste in industrial boilers and furnaces issued at 56 Fed. Reg. 7,134 (1991), with technical amendments at 56 Fed. Reg. 32,688 (1991) and 56 Fed. Reg. 42,504 (1991).

[32] OTA Report, *supra* note 1, at 135.

[33] Municipal-type solid waste is defined in the Code of Federal Regulations. *See* Standards of Performance for Municipal Waste Combustors, 40 C.F.R. § 60.51(a) (1992). Municipal waste is not defined in RCRA but there is a household waste exclusion from the hazardous designation in RCRA. *See* 42 U.S.C. § 6922(i).

[34] OTA Report, *supra* note 1, at 136; *see also Over Half Japan's Municipal Waste Recycled, Most of Rest Incinerated Research Shows*, 18 Env't Rep. (BNA) No. 29, at 1742 (Nov. 13, 1987).

[35] ENVIRONMENTAL QUALITY, THE EIGHTEENTH AND NINETEENTH REPORT OF THE COUNCIL ON ENVIRONMENTAL QUALITY 1987-1988 14 (1989).

[36] Sweden reportedly recycles 50 percent of its waste paper. *See* Bengt Kjellberg, *A Look at One Swedish City*, WASTE AGE, Apr. 1990, at 165.

[37] NAT'L SOLID WASTE MGMT. ASS'N, RECYCLING: TREASURE IN OUR TRASH 4 (1988).

[38] OTA Report, *supra* note 1, at 136.

of various materials found in waste streams, separation can be required prior to collection. Wastes can also be separated at Materials Recovery Facilities (MRFs). About twelve MRFs were in operation in the United States in mid-1989, and more are planned.[39] However, facilities that separate wastes have both high energy requirements and high maintenance costs.[40] While popular during the 1970s, they generally performed poorly. The facilities built during the 1980s appear more successful. In some MRFs, waste that is not recycled is converted to refuse-derived fuel (RDF). The RDF is then burned to produce electricity or steam.[41]

Recycling increases the useful life of MSW landfills, reduces the need for virgin materials to produce new products, and saves energy resources. More significantly, recycling means source reduction which protects against the adverse health and environmental effects of improper MSW disposal; what is not generated harms no one. Recycling facilities, however, can become major hazardous waste sites. It is claimed that fifty of the worst sites on the Superfund National Priorities List (NPL) are recycling facilities and twenty percent of the 1,211 NPL sites were created from the disposal of recycling residues or from recycling practices.[42]

Recycling potential varies among products in the waste stream, and the technology used for recycling depends, of course, on the desired end product.[43] EPA set a goal of reducing the MSW that is generated by twenty-five percent by 1992 and forty percent in 1996.[44] The twenty-five percent reduction level has already been achieved by a number of cities, but such a goal is unlikely to be reached for the United States.[45]

EPA has an "Agenda for Action" to encourage recycling that in-

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[39] *Id.*

[40] *Id.*

[41] *Id.* at 137; *see infra* notes 114–17 and accompanying text.

[42] *Hazardous Materials—HWTC Finds 20 Percent of NPL Sites Were Recycling Facilities*, ENVTL. POL'Y ALERT, Sept. 18, 1991, at 15.

[43] OTA Report, *supra* note 1, at 135–40.

[44] *Solid Waste Management—Draft EPA Policy Boosts Recycling Goal*, ENVTL. POL'Y ALERT, Aug. 22, 1990, at 47.

[45] The 25 percent reduction goal was included in a Feb. 1989 EPA report, THE SOLID WASTE DILEMMA: AN AGENDA FOR ACTION. In Aug. 1990, EPA circulated a draft document, titled THE SOLID WASTE DILEMMA: SOLUTIONS FOR THE 90S, that set a new goal of 40 percent reduction and recycling. *Updated Solid Waste Management Plan Falls Short of New Ideas, Focus Group Says*, 21 Env't Rep. (BNA) No. 19, at 879 (Sept. 7, 1990); *see also Main EPA Options for Incinerator, Landfills Rely on Source Separation*, INSIDE EPA, Aug. 24, 1990, at 4.

cludes the implementation of existing federal procurement guidelines and the development of recycling programs by federal agencies.[46] EPA is also looking for ways to stimulate markets for secondary materials and recycled goods. For example, EPA was concerned with the recycling of lead-acid batteries. As discussed below,[47] EPA took the position that material separation is part of the best demonstrated technology for MSW incineration, but because of White House pressure EPA did not include such requirements in the final regulation.[48] EPA developed draft legislation that would promote pollution prevention and recycling.[49] The aim was to reduce per capita waste generation by ten percent within ten years and to recycle at least twenty-five percent of the solid waste generated within ten years and fifty percent within ten years of enactment. Since the draft bill only set forth goals, and provided numerous exceptions, it was a tentative first step.[50] It did not remove the need for dealing with extant MSW in a meaningful way. Expecting recycling to eliminate most of our wastes is akin to believing in perpetual motion machines.[51] In addition, EPA speaks with two voices on recycling because it considers materials to be hazardous if they are reprocessed off the original production site unless they are used immediately and directly as part of a new product.[52]

Perhaps the most significant barrier to MSW recycling is that the value of the material produced is less than the cost to process the waste. A 1992 study found the average cost of processing a ton of

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[46] U.S. EPA, THE SOLID WASTE DILEMMA: AN AGENDA FOR ACTION (1989); U.S. EPA, BACKGROUND DOCUMENT FOR SOLID WASTE DILEMMA: AN AGENDA FOR ACTION (1989).

[47] *See infra* notes 292–300 and accompanying text.

[48] *See id.*

[49] *EPA Pollution Prevention Draft Bill Mandates Five-Year Plans to Cut Toxics*, INSIDE EPA, Apr. 20, 1990, at 1, 7; *see also Draft of Pollution Prevention Legislation Emphasizes Toxic Releases, Solid Waste Plans*, 20 Env't Rep. (BNA) No. 52, at 1996 (Apr. 27, 1990).

[50] INSIDE EPA, *supra* note 45. On Dec. 19, 1990 the Council on Competitiveness killed a recycling provision in a near-final rule on incinerator emissions because of cost. *OMB Approves Pollution Prevention Strategy*, 21 Env't Rep. (BNA) No. 37, at 1647 (Jan. 11, 1991).

On Jan. 26, 1991, EPA published Notice of its Pollution Prevention Strategy—responding to comments on its draft policy from Jan. 1989 and taking the first steps toward meeting the requirements of the Pollution Prevention Act of 1990. 56 Fed. Reg. 7849, *supra* note 30.

On Apr. 29, 1992 the Senate Environment & Public Works Committee began formal consideration of RCRA amendments. Title II of the bill requires companies that report chemical releases under EPCRA to develop pollution prevention plans. 23 Env't Rep. (BNA) No. 1, at 4 (May 1, 1992).

[51] Thibodeaux, *Hazardous Material Management in the Future*, 24 ENVTL. SCI. & TECH. 456 (1990).

[52] Identification and Listing of Hazardous Waste, 40 C.F.R. §§ 261.1(c)(4), 261.2(c)(3), 261.2(e) (1992); *see* American Mining Congress v. EPA, 824 F.2d 1177, 1189 (D.C. Cir. 1987).

recyclables is $50.30, which is more than the value of the material recovered at an MRF.[53]

### 3. Landfill Disposal

Historically, landfilling has been the most common disposal method in the United States, with an estimated eighty percent (about 130 million tons) of the MSW disposed in approximately 10,000 landfills in 1986.[54] However, many areas of the country are experiencing shortfalls of permitted landfill capacity and rising landfill costs due in substantial measure to more stringent environmental protection requirements.[55] EPA estimated that between 1978 and 1988, seventy percent of the landfills, more than 14,000, closed.[56] By 1990, solid waste produced in the United States increased to 180 million tons, but MSW landfills had decreased to less than 6,000, and half of them were expected to close within five years.[57] New landfills can rarely be sited because of intense political opposition by people living near the proposed facility.[58] Known as the NIMBY ("not in my back yard") or LULU ("locally unwanted land use") phenomenons, this opposition has resulted in a nationwide gridlock on the siting of new facilities.[59] Such opposition is not entirely irrational given the record of disposal

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[53] *MRF Study Shows Processing Costs of Recyclables Exceed Revenues*, 42 J. AIR WASTE MGMT. ASS'N 1552 (1992).

[54] OTA Report, *supra* note 1, at 3; Assessment of Municipal Waste Combustor Emissions under the Clean Air Act, 52 Fed. Reg. 25,399, 25,400 (EPA 1987) (to be codified at 40 C.F.R. § 60) (proposed July 7, 1987).

[55] Increased costs are due to leachate management, groundwater and gas monitoring, closure costs and post-closure costs including 30 years of post-closure leachate control, groundwater and gas monitoring. *See* James Walsh, *More on Sanitary Landfill Costs*, WASTE AGE, Apr. 1990, at 289, 290–91.

[56] NAT'L SOLID WASTE MGMT. ASS'N, GARBAGE THEN & NOW (1988).

[57] *EPA Announces Comprehensive Federal Standards for Municipal Solid Waste Landfills*, 41 J. AIR WASTE MGMT. ASS'N 1424 (1991); *New EPA Regulations Omit Recycling Requirements*, RCRA REV., Apr. 1991, at 6.

[58] *See* Peter Steinhart, *Down in the Dumps*, 102 AUDUBON 290–91 (1986); Detroit Audubon Soc'y v. City of Detroit, 696 F. Supp. 249, 251–52, 255 (E.D. Mich. 1988), *rev'd sub nom.* Ontario v. City of Detroit, 874 F.2d 332, 344 (6th Cir. 1989) (remanding to Michigan state courts), noted in *Detroit Incinerator Case Remanded for State Court Review of Challenges*, 20 Env't Rep. (BNA) No. 2, at 114 (May 12, 1989).

[59] Orlando E. Delogu, *"NIMBY" Is a National Environmental Problem*, 35 S.D. L. REV. 198, 206 (1990). *See* Denis J. Brion, *An Essay on LULU, NIMBY, and the Problem of Distributive Justice*, 15 B.C. ENVTL. AFF. L. REV. 437, 439 (1988); A. Dan Tarlock, *Anywhere But Here: An Introduction to State Control of Hazardous-Waste Facility Location*, 2 U.C.L.A. J. ENVTL. L. & POL'Y 1, 6–11 (1981); A. Dan Tarlock, *Siting New or Expanded Treatment, Storage, or Disposal Facilities: The Pigs in the Parlors of the 1980s*, 17 NAT. RESOURCES L. (ABA) 429, 433–34 (1984). Siting problems are not limited to landfills but exist for other MSW management facilities such as incinerators and recycling plants.

sites that have created environmental problems.[60] A survey of 951 disposal sites on EPA's NPL showed evidence of metals migrating at thirty-four percent of the sites and volatile organic compounds (VOCs) migrating from twenty-eight percent of the sites.[61] At about seventy-five percent of these sites, there was groundwater contamination.[62] The result, however, is that the United States cannot deal with a waste disposal problem that will not disappear.[63] While the public demands state and local governments solve waste disposal problems, they simultaneously organize to block proposed solutions. Indeed, the opposition to any proposed environmental solution has led to a new acronym, NOPE—"Not On Planet Earth"—which has become the rallying cry of opponents to waste disposal facilities.[64] The latest in public response is termed BANANA—"Build Absolutely Nothing Anywhere Near Anything."[65]

The states, under pressure from their constituents, also act to block interstate movement of waste as existing facilities reach capacity.[66] For example, over the past thirty years New York City closed five major landfills and nine incinerators in New York City. The city now relies on three aging incinerators and one landfill. Numerous environmental groups oppose a proposed expansion of incineration capacity.[67] The necessary but increasingly restrictive legal constraints being placed on all forms of waste disposal exacerbate the management problem.[68] Even if recycling and incineration gain favor and eventually dominate MSW management, we will still need landfills to handle the residual ash derived from incinerator operations. Thus, the need for new landfills will become more acute as existing facilities are

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[60] This has led to a significant issue concerning the extent to which municipal governments should be liable under CERCLA. *See* Arnold W. Reitze, Jr. *et al.*, *Cost Recovery by Private Parties Under CERCLA: Planning a Response Action for Maximum Recovery*, 27 TULSA L. J. 365, 378–81 (1992).

[61] DADE W. MOELLER, ENVIRONMENTAL HEALTH 128 (1992).

[62] *Id.*

[63] The move by states to ban imports of wastes has become a major problem in the waste management field. *See Waste Disposal—South Serves As U.S. Dumping Ground, But Resistance Grows*, SUPERFUND REPORT, Jan. 31, 1990, at 3.

[64] Carr, *The NOPE Syndrome*, 12 RESOURCES 11 (1990).

[65] *Public Opposition to Incineration Waste Could Seriously Impede Cleanups, Officials Say*, 23 Env't Rep. (BNA) No. 33, at 2028 (Dec. 11, 1992).

[66] *See* National Solid Wastes Mgmt. Ass'n, Inc. v. Alabama Dep't of Envtl. Mgmt. 910 F.2d 713 (11th Cir. 1990), *modified*, 924 F.2d 1001 (11th Cir.), *cert. denied*, 111 S. Ct. 2800 (1991).

[67] *More Incineration Planned for New York City; Groups Fault Official Pessimism On Recycling*, 22 Env't Rep. (BNA) No. 21, at 1356, 1357 (Sept. 20, 1991).

[68] Most people think of air pollution only from the incineration of solid waste, but air pollution can also come from landfills. Lipstak, ed., *Environmental Engineers' Handbook*, 2 AIR POLLUTION 48 (1974).

retired. More facilities can be expected to close before the new RCRA Subtitle D regulations announced September 11, 1991 come into full effect in October, 1993 (or April 1994 for certain small MSW landfills).[69] The EPA estimates that the cost increase from Subtitle D standards to local governments will be approximately $1.5 billion in annualized costs by the year 2000.[70]

The RCRA Subtitle D regulations establish minimum criteria for all MSW landfills and apply to owners/operators of new MSW landfills, existing MSW landfills, and lateral expansions (although not all of the requirements apply in all situations).[71] "The new regulations specifically deal with location restrictions, facility design and operations, groundwater monitoring and corrective action measures, conditions for closure and post-closure care, and financial responsibility requirements."[72] MSW landfills must comply with the majority of the requirements by October 9, 1993 (or April 9, 1994 for certain small MSW landfills), although financial assurance, groundwater monitoring, and corrective action requirements will be phased in over time.[73]

More specifically, the new regulations restrict the siting of landfills near airports, wetlands, flood plains and fault areas. To be sited, a landfill must either satisfy the requirements of an EPA-approved state permit program or have a composite liner made of synthetic material covering a two-foot clay liner. The landfill must be covered daily and must have methane gas monitors, storm water controls, and programs to prevent hazardous wastes from entering the landfill. Within five years of the rule's publication, all landfills must have groundwater monitors. There are also closure and post-closure requirements that impose technical and financial responsibilities for thirty years after closure.[74]

As many of the MSW landfills in the United States approach capacity, tough choices must be made before the critical date of October 9, 1993 (or April 9, 1994, for certain small MSW landfills). There are a limited number of options: (1) an existing landfill can remain open, and the municipality can apply for a lateral expansion in order to increase

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[69] 56 Fed. Reg. 50,978, *supra* note 11. Recently, the EPA extended the deadline for certain MSW landfills to Apr. 9, 1994. 58 Fed. Reg. 51,536, *supra* note 11.

[70] EPA, ENVIRONMENTAL INVESTMENTS: THE COST OF A CLEAN ENVIRONMENT 5–2 (1991).

[71] Andrew N. Davis *et al.*, *Managing Municipal Solid Waste Landfills*, 1 CONN. ENVTL. COMPLIANCE UPDATE 3, 4 (Nov. 1992).

[72] *Id.* at 4.

[73] *Id. See* 58 Fed. Reg. 51,536, *supra* note 11.

[74] *EPA Announces Comprehensive Federal Standards for Municipal Solid Waste Landfills*, 41 J. AIR WASTE MGMT. ASS'N 1424 (1991).

capacity; (2) a landfill can be closed, and the municipality can set up a transfer station; or (3) a landfill can be closed, and the municipality can contract with private haulers to transport MSW directly out of the municipality.[75] Given these options, a municipality should conduct a cost-benefit analysis to determine whether its landfill should remain open. The costs of compliance with these regulations can be prohibitive. Thus, even if a municipality desires to operate its MSW landfill *after* October 9, 1993 (or April 9, 1994, for certain small MSW landfills), the landfill may not be able to comply with the strict groundwater monitoring and corrective action provisions of the new regulations and may be forced to close.[76] Given the technical and economic burden associated with keeping MSW landfills open, the landfill capacity in the United States is certainly likely to shrink in response to these strict requirements governing their operation. Clearly, we must consider other options for handling our MSW.

The new requirements governing landfills make a permanent solution, such as incineration, increasingly attractive. The adverse byproducts of incineration are often destroyed or neutralized relatively quickly by natural forces, but the toxic potential of landfills can last indefinitely. Moreover, CERCLA liability or exposure associated with land disposal can stretch indefinitely into the future even if all requirements under RCRA have been met.[77]

### 4. Incineration

Incineration should occupy a position in the hierarchy of solid waste disposal options that makes it less desirable than waste prevention/minimization and recycling but more desirable than landfill disposal. It is a permanent solution in that it destroys wastes and can be coupled with energy recovery. Incineration reduces volume by greater than ninety percent, thus requiring far less space in landfills. It does, however, produce potential environmental releases of toxic metals and organics from ash residues.[78] It also results in the production of numerous air pollutants including particulate matter contain-

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[75] Davis *et al.*, *supra* note 71, at 5.

[76] *Id.*

[77] *See generally* Mounteer, *How to Pay for Cleaning Up Co-Disposal Sites: Enlarging the Scope of the Debate*, 23 Env't Rep. (BNA) No. 23, at 1520 (Oct. 2, 1992).

[78] J. A. Kent Simmons & Anthony H. Knap, *Estimates of Ground Level TSP, $SO_2$ and HCl for a Municipal Waste Incinerator to be Located at Tynes Bay—Bermuda*, 41 J. AIR WASTE MGMT. ASS'N 429 (1991).

ing metals, organics (dioxins and furans), acid gases such as sulfur dioxide and hydrochloric acid, and nitrogen oxides.[79]

As mentioned above, during the 1980s, the ever-increasing amount of solid waste, declining landfill capacity, and the stricter legal regulations and rising costs of all solid waste management options led to a renewed interest in use of the MSW incineration option. The NSWMA reports that 136 waste-to-energy plants are operating in thirty-six states and are managing nearly twenty-nine million of the estimated 185 tons of trash generated each year in the United States. This represents about sixteen percent of our trash and the percentage should increase with the addition of nearly one hundred plants that are in the planning, construction or permitting stage.[80] At the same time, organized opposition by citizens and environmentalists makes siting new facilities difficult. With new regulations for MSW incinerators and the implementation of the CAA Amendments of 1990, it is now appropriate to revisit the option of MSW incineration.[81]

## III. MUNICIPAL SOLID WASTE INCINERATION

### *A. History*

The modern U.S. city emerged between 1860 and 1910. During this fifty year period, the U.S. population increased from thirty-one million

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[79] *See* Arlene Levin *et al.*, *Comparative Analysis of Health Risk Assessments for Municipal Waste Combustors*, 41 J. AIR WASTE MGMT. ASS'N 20 (1991).

[80] *136 Waste-to-Energy Plants Operate in 36 States*, 41 J. AIR WASTE MGMT. ASS'N 1160 (1991).

[81] Hazardous waste incineration is subject to a different legal regime that is outside the scope of this article.

Hazardous waste incinerators must meet RCRA requirements and any requirements imposed by the 1990 Clean Air Act Amendments as they are promulgated. Facilities in existence on Nov. 19, 1980 were allowed to apply for "interim status" and then obtain a full permit. New facilities needed a full permit. The regulations for permitted facilities and interim status facilities are found in 40 C.F.R. Parts 264 and 265, respectively. In addition, requirements for obtaining a permit are found in 40 C.F.R. Part 270. The Hazardous and Solid Waste Amendments of 1984 amended RCRA to establish Nov. 8, 1986 as the last day for interim status incinerators to submit a final permit application or close. As of Sept. 1991, six incinerators continue to operate under interim status because EPA or the states have not issued a permit. GAO, HAZARDOUS WASTE, INCINERATOR OPERATING REGULATIONS AND RELATED AIR EMISSION STANDARDS 2–3 (1991).

A related topic, the incineration of hazardous waste at sea (known as ocean incineration), is subject to different legal requirements, but this activity is not presently authorized by law. *See* Arnold W. Reitze, Jr. & Andrew N. Davis, *Reconsidering Ocean Incineration as Part of a U.S. Hazardous Waste Management Program: Separating the Rhetoric from The Reality*, 17 B.C. ENVTL. AFF. L. REV. 687 (1990). Medical waste incineration is subject to a limited regulatory program under RCRA. *See* H. Glasser *et al.*, *An Analysis of Biomedical Waste Incineration*, 41 J. AIR WASTE MGMT. ASS'N 1180, 1181 (1991).

to ninety-one million. However, solid waste management did not keep pace with population growth. As a result, cities were not very pleasant places to live. Until the advent of the automobile, the major contributor to MSW was animals. One thousand horses can discharge 500 gallons of urine and ten tons of manure in an eight-hour work day.[82] During the 1866 cholera epidemic, New York City authorities removed some 160,000 tons of manure from vacant lots.[83] In 1914 it was reported that 82,000 horses, cows, and mules in Chicago produced 600,000 tons of dung per year.[84] In the nineteenth century, pigs freely roamed the streets of New York City feeding on garbage.[85] The practice of using hogs to consume MSW remained common until the mid-1950s. In 1941, a federal study of cities with populations greater than 25,000 reported that an estimated twenty-seven percent of their garbage was fed to swine.[86]

As the solid waste accumulated across the United States, coastal cities began to dump much of it into the ocean. Today, such practices are unacceptable and almost completely legally phased out.[87] Most of the waste, however, went to open dumps where typically it was burned. Extensive dumps in northern New Jersey in the 1950s and 1960s would burn for months, often blanketing the region with an odoriferous smoke cloud for days at a time. Occasionally the legal system got involved in a public or private nuisance suit[88] or in enforcing a local ordinance,[89] but this was the exception. During the 1960s, the limited federal efforts in the solid waste field focused on converting dumps into sanitary landfills. Sanitary landfills, with each day's waste contained in cells surrounded and covered by dirt, would keep MSW from burning.[90] When the CAA of 1970 was enacted, it essen-

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[82] *See* AMERICAN PUBLIC WORKS ASS'N, HISTORY OF PUBLIC WORKS IN THE UNITED STATES 434 (1976) [hereinafter APWA].

[83] CHARLES E. ROSENBERG, THE CHOLERA YEARS 210 (1962).

[84] APWA, *supra* note 82, at 434.

[85] *Id.*

[86] Between 1953 and 1955, the spread of vesicular exanthema among swine necessitated the slaughter of more than 400,000 swine to control this livestock disease. This led to states passing laws requiring wastes to be cooked before being fed to hogs, and the resultant cost of processing wastes led to the abandonment of this practice. *See* APWA, *supra* note 82, at 448.

[87] *See* Ocean Dumping Ban Act of 1988, 33 U.S.C. § 1414(b) (1988); *see also Ocean-Dumping Days Ending for New York*, WASH. POST, June 24, 1989, at A14.

[88] *See generally* William L. Prosser, *Private Action for Public Nuisance*, 52 VA. L. REV. 997 (1966); Julian C. Juergensmeyer, *Control of Air Pollution Through the Assertion of Private Rights*, 1967 DUKE L. J. 1126 (1967); Harold W. Kennedy & Andrew O. Porter, *Air Pollution: Its Control and Abatement*, 8 VAND. L. REV. 854 (1954–1955).

[89] *See, e.g.*, Oriental Boulevard Co. v. Heller, 265 N.E.2d 72 (N.Y. 1970); City of Chicago v. Fritz, 184 N.E.2d 713 (Ill. App. Ct. 1962).

[90] APWA, *supra* note 82, at 450; ARNOLD W. REITZE, JR., ENVIRONMENTAL LAW 2–13 (2d ed. 1972).

tially banned uncontrolled burning, thereby leading to a renewed interest in the construction of incinerators by local governments.[91] An incinerator's major advantage is that it reduces solid waste seventy to eighty-five percent by weight and eighty-five to ninety-five percent by volume.[92] The heat value of MSW offers the possibility of converting waste to usable energy. Incineration also destroys pathogens and some toxic chemicals, but, as a trade-off, produces harmful air emissions. However, compared with many of the alternatives, the risks from incineration appear modest.

While incineration has not been a major method of MSW management, its use dates back to the nineteenth century. The first municipal incinerator was constructed in Allegheny, Pennsylvania in 1885, and other cities soon followed by building "crematories" for their MSW.[93] During the 1890s, Washington, D.C. operated an incinerator during the winter months in lieu of barging MSW down the Potomac River to a site south of Alexandria, Virginia.[94] In 1924, Atlanta, Georgia sold surplus steam produced by an incinerator to the Atlanta Gas Light Company.[95] A second incinerator built in 1927 also produced steam that was sold to the Georgia Power Company.[96] During the late 1930s, the number of MSW incinerators in the United States declined substantially with most MSW ending up in landfills.[97] As more stringent regulations began to be placed on MSW disposal practices during the 1970s, interest in incineration was rekindled. In 1989, EPA claimed that more than 200 MSW incinerators were in operation,[98] with 136 of these facilities being waste-to-energy plants.[99]

Incinerator facilities are not evenly distributed geographically. Currently, the greatest incineration capacity exists, in descending order, in Florida, New York, Massachusetts, Ohio, and Virginia.[100] More than forty percent of the MSW incinerators are located in New England and the mid-Atlantic regions combined; few are located in

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[91] OTA Report, *supra* note 1, at 217.

[92] *See id.* at 247.

[93] APWA, *supra* note 82, at 435.

[94] *Id.*

[95] *Id.* at 449.

[96] *Id.*

[97] *See id.* at 449–50.

[98] EPA claimed in 1987 that there were 111 combustors incinerating 6 million tons of MSW a year with substantial growth expected. 52 Fed. Reg. 25,400, *supra* note 54. In their 1989 proposed regulations, EPA claimed there were over 200 existing MSW incineration plants (over 450 individual municipal waste combustors (MWCs)) with a total existing MWC capacity of about 95,000 milligrams/day (100,000 tons/day) that would be subject to emission guidelines. 54 Fed. Reg. 52,218, *supra* note 10.

[99] *See supra* note 80 and accompanying text.

[100] OTA Report, *supra* note 1, at 221.

the Rocky Mountains or further west.[101] Today, well-designed and well-operated incinerators may offer a viable solution to some of the MSW disposal problems.[102] However, while improved technology has removed most of the nuisance problems associated with incineration, public opposition has made siting new facilities extremely difficult.[103]

### *B. Incineration Technology*

Three types of incinerators are commonly used to burn MSW: mass burn, modular, and refuse-derived fuel (RDF) MSW incinerators.[104] Mass burn MSW incinerators vary widely in size, ranging from 50 to 1000 tons per day capacity.[105] Typically each plant has two or three incinerators. In a mass burn incinerator, wastes are burned without preprocessing, except to remove very large items such as washing machines.[106] In a mass burn system, hydraulic rams or pusher grate sections are used to move MSW into the incinerator and then convey it through the incinerator.[107] Modern mass burn incinerators often have waterwalls to cool the combustion chamber and to recover heat.[108] Older mass burn incinerators may have a refractory wall design and may lack the capability of recovering heat.[109]

Modular MSW incinerator systems are typically small, ranging from 5 to 120 tons per day of burning capacity and having one to four incinerators at each site.[110] Modular incinerators usually use two or more combustion chambers to provide better combustion. The configuration of these chambers and how much air is introduced allows for various classifications of modular incinerators. Most of these devices have refractory-lined combustion chambers.[111] Some recently constructed modular incinerators recover heat using waste heat boilers, but the older incinerators do not.[112] These incinerators usually do

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[101] *Id.*

[102] In Denmark, 60 percent of its combustible solid wastes are incinerated. 40 plants burn domestic, commercial, and industrial wastes and in the process produce steam that meets ten percent of the nation's demand for space heating. In addition, some of the plants generate electricity. Prall Culviner, *Denmark Chooses Combustion*, WASTE AGE, Apr. 1990, at 179.

[103] Esther Suskind & Lawrence E. Suskind, *The Incineration Conflict: Addressing Public Concerns*, 9 ENV. IMPACT ASSESSMENT REV. 317 (Sept. 1989).

[104] 54 Fed. Reg. 52,220, *supra* note 10.

[105] *Id.*

[106] *Id.*

[107] *Id.*

[108] *Id.*

[109] *Id.*

[110] *Id.*

[111] *Id.*

[112] *Id.*

not preprocess wastes but accept all wastes that can be physically handled by the system.[113]

Refuse-derived fuel (RDF) incinerators burn pretreated and shredded MSW.[114] The processing stage varies from merely removing large items and shredding, to extensive pretreatment that produces a finely divided fuel with minimal noncombustible material.[115] The RDF is usually fed with a stoker into the incinerator and onto a moving grate. Some facilities mix auxiliary fuel with the waste for better combustion. RDF incinerators are usually medium to large; they typically recover heat;[116] and they have a burning capacity ranging from 300 to 1000 tons per day. Plants typically have two to four incinerators at a site. One drawback to RDF facilities is that they emit twice the quantity of dioxins and furans as mass burn facilities.[117]

There are about a dozen old MSW incinerators in the United States that utilize other technologies, including batch-fed refractory wall incinerators, small modular systems that burn unprocessed MSW, and other technology systems including pyrolysis, and fluidized bed.[118] New incinerators normally use one of the three major technology systems described above.[119]

Both mass burn and RDF incinerator systems can be designed to recover heat. These waste-to-energy systems are able to produce steam or electricity. The construction of such energy-recovery facilities has been encouraged by the Public Utility Regulatory Policies Act (PURPA)[120] which requires electric utilities to purchase this electric power at the price they would pay to generate additional power. This avoided cost is attractive to independent power producers.[121]

In 1990, 128 waste-to-energy incinerators, operating in thirty-six states, had the capacity to burn 84,246 tons per day. There are twelve plants that can process 6,040 tons per day to produce RDF that can then be burned at other facilities.[122] These facilities produce electric power equivalent to nearly twenty-seven million barrels of oil each

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[113] *Id.*

[114] *Id.*

[115] *Id.*

[116] *Id.*

[117] *See id.*

[118] See OTA Report, *supra* note 1, at 217.

[119] *See* 54 Fed. Reg. 52,220, *supra* note 10.

[120] 16 U.S.C. §§ 2601–2692 (1988 & Supp. IV 1992).

[121] DEP'T OF ENERGY, ENERGY SECURITY: A REPORT TO THE PRESIDENT OF THE UNITED STATES 157 (1987).

[122] *Record New Waste-to-Energy Capacity Built in 1990 Joins 128 Existing Plants*, 41 J. AIR WASTE MGMT. ASS'N 10 (1991). Note that other sources say that in 1991 there were 136 waste-to-energy plants. *See supra* note 80 and accompanying text.

year. There are seventy-one planned MSW incinerators and eight inactive facilities that are expected to become operational soon.[123] Thus, incineration could be a partial solution to the MSW problem and reduce petroleum consumption if public opposition (i.e., the NIMBY syndrome) could be overcome.[124]

Public opposition usually involves the following: concern with health and environmental risks from air emissions and ash disposal; a perceived negative effect on recycling efforts; a belief that the people living in the vicinity of the facility are not beneficiaries of the facility; a concern as to the quality of the operation of the facility; the concern over adverse impacts on property values; and contentions that sites are selected to avoid middle- or high-income neighborhoods.[125] Many of these NIMBY issues are similar to those that have gridlocked local governmental efforts to provide other services to their communities. The siting of other MSW management facilities as well as prisons, half-way houses, drug treatment centers, mental health centers, and other facilities has been similarly thwarted.[126] The concern that incineration destroys efforts at source reduction means that some environmentalists will oppose incineration regardless of its comparative safety.[127]

Opposition is also strengthened by our incomplete knowledge of incinerator effects and the impossible standards often being imposed on governmental officials. In addition, citizens distrust government and believe that incinerators will be improperly operated. Unfortunately, citizen concern over incineration is not entirely irrational given the track record of governmental supervision. The public cries for a "no risk" standard to be imposed on incinerators. This demand for absolute protection from the effects of hazardous materials is not usually imposed on other activities.

To burn MSW effectively, an incinerator must meet the appropriate "three Ts" of incineration for the material being burned: adequate temperature, adequate time, and adequate turbulence.[128] For MSW,

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[123] *Waste to Energy—Industry Study Says Combustion Could Cut Oil Demand*, ENVTL. POL'Y ALERT, Jan. 23, 1991, at 17.

[124] The potential for increased incineration is high as EPA in its 1987 proposed rules claims that only 5–6 percent of MSW is incinerated. *See* 52 Fed. Reg. 25,400, *supra* note 54.

[125] OTA Report, *supra* note 1, at 223.

[126] *See supra* note 59.

[127] *See, e.g., EPA Asks for Millions in Hazardous Waste Fines*, WASH. POST, Sept. 29, 1993, at A24 (spokesman for Greenpeace stated that incinerators were "the drunk drivers of polluters [and] shouldn't just be fined . . . [t]hey should be pulled off the road.")

[128] *See generally* Williams *et al., 3-D Flow Modeling of a Hazardous Waste Incinerator*, 38 JAPCA 1050 (1988); Lee, *Research Areas for Improved Incinerator System Performance*, 38 JAPCA 1542 (1988).

this means about a one-to-two second residence time for flue gases in the combustion zone, although, with adequate turbulence, combustion is almost instantaneous if the temperature is sufficient.[129] The minimum temperature for mass burn and RDF incineration systems is 1,800°F.[130] Higher temperatures produce substantial oxides of nitrogen ($NO_x$) emissions and can volatilize metals. Lower temperatures decrease these problems but increase the emission of products of incomplete combustion (PICs).[131] High temperatures are also needed to destroy organic compounds such as dioxins, but these compounds can still be formed during and after combustion as reactions continue in the hot flue gases. To minimize these environmental problems, MSW incinerators must ensure adequate mixing of heterogeneous wastes to achieve adequate combustion. They also must ensure sufficient heat value in the waste either through such mixing or through the use of auxiliary fuel to create the conditions for complete burning.[132]

Air emissions from incinerators contain many substances because of the various wastes burned in the systems. Older incinerators tend to have high emissions. Modern incinerators with better designs and computerized combustion controls have lower emissions. State-of-the art pollution controls can further limit emissions.

Incinerators emit particulate matter (PM). While some PM is non-combustible material from the original waste input, some is condensed gases from material vaporized during incineration but cooled into or onto particles. Particulates can be silicates from glass, inorganic oxides, and metals. The metals commonly found as particulates include iron, aluminum, and cadmium. Other toxic trace metals may also be present.[133]

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[129] Destruction of harmful chemicals through incineration is so rapid that much of the regulatory concern with incineration is over undesirable byproducts created during or after high temperature combustion. Thus, regulatory efforts often place maximum temperature limits on incineration. *See* Standards of Performance for New Stationary Sources; Municipal Waste Combustors, 56 Fed. Reg. 5488, 5491, 5517 (EPA 1991) (to be codified at 40 C.F.R. §§ 51, 52, 60) (proposed Feb. 11, 1991). Combustion efficiency above 99.9 percent is usually considered to result in adequate organic destruction. Combustion efficiency can be determined from $CO/CO_2$ measurement.

$$\text{Combustion efficiency} = \frac{CO_2}{CO_2 + CO} \times 100$$

[130] James D. Kilgroe, *Combustion Control of Trace Organic Air Pollutants from Municipal Waste Combustors*, 9 ENVTL. IMPACT ASSESSMENT REV. 199, 205 (1989).

[131] Stephen T. Washburn *et al.*, *Human Health Risks of Municipal Solid Waste Incineration*, 9 ENVTL. IMPACT ASSESSMENT REV. 181 (1989).

[132] OTA Report, *supra* note 1, at 225. There must also be an adequate supply of waste. *See* La Crosse County v. Gershman, Brickner & Bratton, 982 F.2d 1171 (7th Cir. 1993).

[133] OTA Report, *supra* note 1, at 230.

In addition, organic compounds (including dioxins and furans) and trace heavy metals can be absorbed onto PM and be emitted.[134] Heavy metals such as zinc, lead, cadmium, mercury, and arsenic volatilize in elemental form, although mercury is often present as mercury chloride. As flue gases cool, the metals condense onto fly ash[135] or join together to form a material known as fume. The distribution of metals in relation to the size of the fly ash particle varies by the type of metal. Most metals are found on particles less than ten microns (10 um) in diameter. These small particles are the most serious air pollutants, as they can enter the respiratory system easily. The larger particles also pose health risks through transfer in foodchain pathways as well as by direct ingestion following inhalation.[136]

Nitrogen oxides ($NO_x$) are produced during MSW incineration by the conversion of nitrogen compounds in wastes and by reactions at high temperatures with nitrogen and oxygen in the air, that produce $NO_x$ by thermal fixation.[137] Since MSW incinerators usually operate at about 1,800°F, which is below the temperature of significant $NO_x$ production, most $NO_x$ is created by conversion. Yard and food wastes are the major contributors to $NO_x$ formation.[138]

Acid gases are emitted from incinerators as a function of the elements of chlorine, sulfur, bromine, and fluorine in the MSW inputs. The most significant acid gas is usually hydrogen chloride (HCl) which is produced from incineration of PVCs and other chlorine containing materials. Other acid gases produced during MSW incineration include sulfur dioxide ($SO_2$) and usually minor amounts of sulfuric acid, hydrogen bromide, and hydrogen fluoride. Sulfur emissions from MSW incinerators, however, tend to be lower than other sources of air pollution that burn oil or coal.[139]

The air pollutants that are the subject of the most controversy are the seventy-five chemical compounds known as chlorinated dioxins (dibenzo-p-dioxins, or PCDDs) and 135 chlorinated furans (dibenzofurans, or PCDFs).[140] These are the toxics of greatest concern among

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[134] *Id.*

[135] *See infra* note 186 and accompanying text.

[136] OTA Report, *supra* note 1, at 231.

[137] $NO_x$ emission limits also force incinerators to limit temperatures. *See* F. Thomas DePaul & Jerry W. Crowder, *Control of Emissions From Municipal Solid Waste Incinerators*, 169 POLLUTION TECH. REV. 64 (1989).

[138] OTA Report, *supra* note 1, at 230.

[139] *Id.*

[140] The many polychlorodibenzodioxins (PCDDs) and polychlorodibenzofurans (PCDFs) are often expressed in terms of toxic equivalents to one dioxin isomer—2,3,7,8-TCDD. Toxic equivalents for dioxins and furans are denoted as TEDFs. Levin *et al.*, *Comparative Analysis of*

the many organic chemicals found in trace amounts in MSW incinerator emissions. Dioxin is the term frequently used as shorthand for the seventy-five PCDDs, but it is also used to designate 2,3,7,8-TCDD, the most harmful form of the dioxin chemicals. Dioxins in MSW occur in products such as plastics, bleached paper, pesticides, and wood preservatives.[141] Dioxins can also be formed during combustion by either direct conversion of precursor chemicals or combustion of non-precursor organic compounds with a chlorine donor. In addition, dioxins can be formed after combustion, when fly ash particles act to convert undestroyed precursors into dioxins/furans.[142] MSW incinerators are usually considered to be more serious sources of dioxin than hazardous waste incinerators[143] because MSW fly ash usually has a higher concentration of organic compounds and less effective combustion and air pollution control systems.[144]

Pollutants in flue gases can be controlled by: removing materials from MSW prior to combustion; destroying them at high temperatures; keeping them from being created by controlling combustion parameters; or removing them from flue gases using modern pollution control equipment.

The effect of material separation on emissions is obviously related to what is separated out prior to incineration. For example, presorting to remove metals has been shown to significantly reduce metal emissions.[145] Removing household and automobile batteries can significantly reduce lead, mercury, and cadmium from emissions.[146] Removing chlorine donors to prevent dioxin and furan formation cannot be realistically achieved at this time. Nevertheless, eliminating plastics can help and would also reduce emissions of polycyclic aromatic hydrocarbons (PAHs).[147]

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*Health Risk Assessments for Municipal Waste Combustors*, 41 J. AIR WASTE MGMT. ASS'N 20, 21 (1991).

[141] *See* Robert D. Leaversuch, *Incineration, Is It a Real Option? Or Is It Just an Illusion?* MODERN PLASTICS, May, 1989, at 34.

[142] OTA Report, *supra* note 1, at 226. *See also* Prakash Acharya *et al.*, *Factors That Can Influence and Control the Emissions of Dioxins and Furans from Hazardous Waste Incinerators*, 41 J. AIR WASTE MGMT. ASS'N 1605 (1991); Ramana Kolluri & Elmar Altwicker, *A Model to Analyze Formation of Dioxins in the High Temperature Regions of Municipal Solid Waste Incinerators*, 42 J. AIR WASTE MGMT. ASS'N 1577 (1992).

[143] Acharya *et al.*, *supra* note 142. Hazardous waste is defined *infra* note 215.

[144] E. Timothy Oppelt, *Incineration of Hazardous Waste—A Critical Review*, 37 JAPCA 558 (1987).

[145] OTA Report, *supra* note 1, at 231.

[146] *Id.* at 105–07, 156–61.

[147] Yasuda *et al.*, *Basic Research on the Emissions of Polycyclic Aromatic Hydrocarbons Caused by Waste Incineration*, 39 JAPCA 1557 (1989).

Because dioxins and furans condense onto fly ash, they are removed by air pollution controls that remove particulate matter. RCRA "dioxin rules" require that incinerators show a destruction removal efficiency of 99.9999 percent for chlorinated dioxins.[148] Some facilities have achieved even more effective removal. However, little information exists concerning removal efficiencies over long time periods. Also, there is scant information on the amounts of dioxin emitted from poorly operated facilities.[149]

Removing yard wastes prior to combustion would aid $NO_x$ control for MSW incineration.[150] Composting yard wastes would benefit the environment.[151] $NO_x$ control during combustion can be accomplished by combustion modification, including flue gas recirculation. $NO_x$ can also be reduced after combustion by selective catalytic reduction and by ammonia injection.[152] $NO_x$ is difficult to control, and a full discussion of this subject is beyond the scope of this paper. However, $NO_x$ formation from MSW incinerators is minor compared with that emitted from electric power plants, heavy industrial boilers, or automobiles.[153]

Acid gases can be controlled with "scrubbers" which use alkaline reagents that react with the flue gases to produce salts. These salts are collected and sent to landfills for disposal. Scrubbers vary in design; they can be wet, dry, and spray dry. Wet scrubbers under optimal conditions remove about ninety-five percent of the HCl and eighty-five percent of the $SO_2$, but they have been considered an experimental technology in the United States and, therefore, are not legally a best demonstrated technology (BDT).[154] Dry scrubbers use more lime than wet scrubbers, which presents a solid waste disposal problem, but dry scrubbers do not produce contaminated wastewater. They remove about ninety percent of the HCl and seventy percent of the $SO_2$. Spray dry scrubbers have achieved even higher removal efficiencies. Dry injection is another technology that is used extensively in Japan but has not been used in the United States.[155]

Particulate matter can be removed from flue gases using electrostatic precipitators (ESPs) and fabric filters. Removal efficiencies for

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[148] Clyde R. Dempsey & E. Timothy Oppelt, *Incineration of Hazardous Waste: A Critical Review Update*, 43 J. AIR & WASTE MGMT. ASS'N 25, 29 (1993).

[149] OTA Report, *supra* note 1, at 232.

[150] *See id.*

[151] *See* Dan Goldberg, *Can Grass Clippings Be Composted?*, WASTE AGE, Apr. 1990, at 192.

[152] OTA Report, *supra* note 1, at 233.

[153] The two major sources of nitrogen oxides in 1989 were fuel combustion (56 percent) and transportation (39 percent). EPA, NATIONAL AIR QUALITY AND EMISSIONS TRENDS REPORT, 1991 I–8 (1991).

[154] 54 Fed. Reg. 52,265, *supra* note 10.

[155] OTA Report, *supra* note 1, at 234–35.

the best ESPs can exceed 99.7 percent. Fabric filters or baghouses use a series of cylindrical bags through which the flue gases are filtered. Removal efficiencies can exceed 99.99 percent. Fabric filters are considered more efficient than ESPs in collecting particles smaller than two microns, but either approach can achieve extremely high levels of particulate removal.[156] Since many of the metals in incinerator emissions condense onto fly ash particles, metal removal of over ninety-nine percent can be achieved for most metals with ESPs and fabric filters. However, mercury and mercury chloride emissions are difficult to remove and are more effectively controlled with scrubbers than with ESPs.[157] One problem with controlling metals, as well as other toxics produced in incinerator gases, is that their concentration is so low that it is often at or below the detection limits of existing instrumentation.[158]

### *C. Regulation Prior To The 1990 CAA Amendments*

#### 1. Overview

The regulation of MSW incinerators (*a.k.a.* municipal waste combustors (MWCs)) began with the promulgation in 1974[159] of new source performance standards (NSPS) for PM emissions from MSW incinerators with more than fifty tons per day capacity under section 111(b) of the Clean Air Act (CAA).[160] Maximum emissions were limited to 0.08 grains of PM per dry standard cubic foot (dscf) of exhaust gas.[161]

MSW incinerators are facilities used to burn more than fifty percent household waste as well as wastes from institutional, commercial, and some industrial sources that do not burn industrial process wastes or medical wastes. MSW incinerators include those that burn refuse-derived fuel (RDF), which is solid waste that is shredded and classified by size before combustion.[162] Hazardous waste incinerators are not covered by the MSW regulations; instead, they are regulated under RCRA.[163] Sewage sludge, which is incinerated, is regulated by a

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[156] *Id.* at 238.

[157] *Id.*

[158] The technical literature is rich with papers discussing the problems of monitoring incinerators. *See, e.g.*, E. Timothy Oppelt, *supra* note 144, at 567.

[159] 52 Fed. Reg. 25,400, *supra* note 54.

[160] Standards of Performance for Municipal Waste Combustors, 40 C.F.R. § 60.50 (1992).

[161] 52 Fed. Reg. 25,400, *supra* note 54.

[162] 54 Fed. Reg. 52,209, *supra* note 10; *see supra* notes 104–17 and accompanying text.

[163] 42 U.S.C. §§ 6901–6992k. The regulations are found at 40 C.F.R. Parts 264, 265, subpart O (1992). Proposals to tighten standards are found at 54 Fed. Reg. 45,311 (1989) and 55 Fed. Reg.

NSPS[164] under the CAA and by regulations under the Clean Water Act (CWA).[165] Medical waste incineration will be regulated under a separate regulation which has a statutory deadline of November 15, 1992 but has not yet been promulgated.[166] Ocean incineration of wastes is neither done in U.S. waters, nor allowed under U.S. law.[167]

In 1986, standards for new large industrial boilers were promulgated that included a PM standard of 0.1 pounds per million BTU (which is approximately 0.03 grains per dry standard cubic foot of stack gas (gr/dscf)). MSW incinerators with heat recovery facilities, that are equipped with boilers and heat recovery incinerators of roughly 200 tons per day of waste input, are large enough to fall under the industrial boiler standard. Therefore, some new MSW incinerators were subject to the more stringent 1986 regulations.[168]

In addition, mercury has been subject to an ambient air guideline of 1 ug/$m^3$ under CAA section 112[169] and lead is subject to an ambient air quality standard under CAA sections 108–110.[170] The criteria pollutants,[171] $PM_{10}$, $SO_2$, CO, $O_3$, and $NO_2$ are also subject to regulation under the applicable state implementation plan (SIP)[172] which, since 1977, also includes requirements applicable to areas meeting ambient

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17,862 (1990). Polychlorinated biphenyls (PCBs) are regulated under the Toxic Substances Control Act § 6(e), 15 U.S.C. § 2605(e) (1988). *See* Procedures for Rulemaking under § 6 of Toxic Substances Control, 40 C.F.R. §§ 750.10–750.21 (1992). According to one source there are currently 16 commercial hazardous waste incinerators in operation in the U.S. and another one at the test burn stage. Tom Kenworthy, *Incinerator In Ohio Poses Balancing Test for Clinton-Gore Policies*, WASH. POST, Jan. 2, 1993, at A4. Another source reports there are 18 commercial hazardous waste incinerators in the U.S. and 200 other industrial incinerators and cement kilns. *Judge Orders Shutdown at Dioxin Burn Site; Defendants Appeal Decision to Eighth Circuit*, 7 Toxics L. Rep. (BNA) No. 38, at 1118, 1119 (Feb. 24, 1993).

[164] Standards of Performance for Sewage Treatment Plants, 40 C.F.R. § 60.150 (1992).

[165] State Sludge Management Program Regulations, 40 C.F.R. § 501.2 (1992).

[166] About two-thirds of all U.S. hospitals dispose of infectious waste using on-site incineration. There are an estimated 6,000 substandard medical waste incinerators, which have been regulated by state governments only. Carol Ehrle, *Hazardous to Your Health*, RESOURCES, Dec. 1991, at 6. The 1990 CAA requires federal regulation by Nov. 15, 1992. 42 U.S.C. § 7429(2)(1)(C) (Supp. II 1990). The April 26, 1993, EPA Regulatory Agenda does not project a proposed rule until Mar. 1994 and a final rule before Aug. 1995. EPA, Regulatory Agenda, 58 Fed. Reg. 24,996, 25,059 (EPA 1993).

[167] *See* Reitze & Davis, *supra* note 81.

[168] 52 Fed. Reg. 25,400, *supra* note 54.

[169] The 1990 CAA Amendments are designed to expand the number of regulated sources and degree of control. *See infra* notes 235–68 and accompanying text.

[170] 42 U.S.C. §§ 7408–7410 (Supp. II 1990).

[171] Nitrogen oxides and hydrocarbons may also be regulated to reduce ozone, which is a criteria pollutant. *See* NATIONAL RESEARCH COUNCIL, RETHINKING THE OZONE PROBLEM IN URBAN AND REGIONAL AIR POLLUTION 163 (1991).

[172] 52 Fed. Reg. 25,405, *supra* note 54.

air quality standards[173] and requirements imposed on nonattainment areas.[174]

In section 102 of the 1984 Hazardous and Solid Waste Amendments (HSWA) of RCRA, Congress directed EPA to study dioxin risks from MWCs.[175] In June, 1985, the Administrator announced EPA's air toxic strategy. It was to include studying MSW incinerators that emit multiple pollutants. On August 5, 1986, the Natural Resources Defense Council (NRDC) and the states of New York, Rhode Island, and Connecticut petitioned the Administrator of EPA to regulate air emissions from new and existing MSW incinerators using the CAA sections 111 and 112. On July 7, 1987, EPA announced an advance notice of proposed rulemaking (ANPRM) to regulate emissions from new or modified MSW incinerators as well as from existing sources.[176] Proposed rules for both existing and new MSW incinerators were promulgated December 20, 1989.[177] Existing facilities could also be regulated by the states as part of the SIP development[178] and might be subject to the nonattainment area provisions.[179] EPA issued guidance documents as to what is the appropriate technology—usually referred to as "best demonstrated technology" or BDT.[180] New sources were required to incorporate gas scrubbers, combustion controls, and particulate controls.

Some states specifically regulate MSW incinerators. For example, Connecticut, Florida, Indiana, Maine, Massachusetts, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Vermont, and Wisconsin require scrubbers. Some states also specify combustion and particulate controls, and some have adopted minimum operating standards.[181] Some states have adopted $NO_x$ emission limits for MSW incinerators. Other states such as California, Connecticut, New Jersey, and New York require "best available control technology" (BACT) for $NO_x$ control.[182] About ten states have HCl limits requiring ninety percent removal or emission limits of thirty to fifty parts per million (ppm). Some states impose $SO_2$ removal efficiency require-

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[173] 42 U.S.C. §§ 7470–7492 (1988 & Supp. II 1990).

[174] 42 U.S.C. §§ 7501–7515 (1988 & Supp. II 1990).

[175] Marta K. Richards, *The Present and Future EPA Incineration Research Facility*, 39 JAPCA 1309 (1989).

[176] 52 Fed. Reg. 25,399 (1987).

[177] 54 Fed. Reg. 52,251, *supra* note 10.

[178] 42 U.S.C. § 7410 (Supp. II 1990).

[179] 42 U.S.C. §§ 7501–7515 (1988 & Supp. II 1990).

[180] 52 Fed. Reg. 25,399, *supra* note 54.

[181] OTA Report, *supra* note 1, at 243, 246.

[182] *Id.* at 244.

ments, usually seventy to eighty percent, and some set emission limits, usually thirty to one hundred ppm.[183] For particulates, the federal standard was 0.046 gr/dscf, but states vary in their requirements and several states have set limits as low as 0.01 gr/dscf. Few states have set particulate emission standards for metals.[184] The federal regulations created in the 1970s and 1980s for MSW incinerators only regulated particulates generally.[185] These regulations ignored the more specific metal particulates emitted by MSW incinerators, even though controlling particulates in general helps to control specific pollutants emitted as solids.

The legal status of MSW incinerator ash[186] has been unclear and, as a result, has retarded further use of incineration technology. Since 1980, EPA has considered RCRA's "household waste exclusion" to exempt MSW incinerators from being regulated as RCRA Subtitle C hazardous waste treatment facilities.[187] Although incinerator ash was not listed as a hazardous waste, it nevertheless qualified as hazardous if it satisfied *any* of the four "hazardous characteristics" specified by federal law;[188] namely, ignitability, corrosivity, reactivity, or toxicity.[189]

In 1984, Congress amended RCRA to exclude from Subtitle C all waste-to-energy facilities that have a program to exclude hazardous waste inputs.[190] However, Congress did not specify how ash from

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[183] *Id.* at 244–45.

[184] *Id.* at 245.

[185] *Id.* at 246, Table 6–5.

[186] Fly ash is carried in the flue gases during combustion but after capture in air pollution control devices it is usually placed in a landfill. Bottom ash is the heavier uncombusted or partially combusted material that accumulates in the incinerator. Fly ash from U.S. incinerators is about 15 to 30 percent by weight and 5 to 15 percent of the total ash. A range of metals and organic compounds is found in the ash. Volatile metals such as arsenic, mercury, lead, cadmium, and zinc tend to be more concentrated in fly ash. Less volatile metals such as aluminum, chromium, iron, nickel, and tin are more commonly concentrated in bottom ash. Organic chemicals such as dioxins and PCBs tend to be concentrated in fly ash. Other organics, such as polycyclic aromatic hydrocarbons (PAHs) tend to be found in bottom ash. MSW incinerator ash may contain higher concentrations of toxic material than coal ash. The most common disposal method is to use a specialized ash landfill, but EPA estimates that 17 percent of incinerator ash is commingled with MSW. However, the fate of much of the ash generated in the United States is unknown. The reason for concern is that ash often contains hazardous chemical constituents, which may leach out and contaminate surface or ground water. The presence of heavy metals is of particular public health concern. The incineration process does not destroy these hazardous constituents but rather concentrates and transforms them into a form that is more easily transported to, and assimilated by, humans, plants, and animals. *Id.* at 247.

[187] 42 U.S.C. § 6921(i).

[188] The identification of hazardous waste is found in 42 U.S.C. § 6921(a), but the four characteristics are developed in the regulations. Identification and Listing of Hazardous Waste, 40 C.F.R. § 261 (1992).

[189] *Id.*

[190] 42 U.S.C. § 6921(i).

MSW incinerators should be characterized. In 1985, EPA stated that ash would be considered hazardous if it failed an extraction procedure (EP) toxicity test.[191] However, ash can vary daily in its toxic characteristics. Some reported data gathered from MSW incinerators indicates that fly ash failed EPA's EP toxicity test every time because of high lead and cadmium levels. Also bottom ash, both alone and combined with fly ash, failed the EP toxicity test twenty-five to fifty percent of the time.[192] In addition, EPA did not enforce ash regulations and the guidelines under Subtitle D for managing ash are ill-developed.[193] In 1988, EPA announced it would not provide further guidance on ash treatment until it received directions from Congress.[194]

In late 1989, the Environmental Defense Fund (EDF) lost cases before the U.S. District Courts for the Southern District of New York[195] and the Northern District of Illinois.[196] The Illinois case held that ash remaining after incineration of household waste and non-hazardous commercial waste is exempt from hazardous waste regulation.[197] The New York case held that incinerator ash may be exempt from hazardous waste regulation even when tests show it to be toxic.[198] EDF appealed the New York decision and lost again. The U.S. Court of Appeals for the Second Circuit ruled that ash produced from an exempted facility was not hazardous waste even if it was hazardous under EPA standards.[199] It also ruled that the 1990 CAA had not made the dispute moot.[200] The U.S. Supreme Court refused to review the decision.[201] But only days earlier, on November 19, 1991, the U.S. Court of Appeals for the Seventh Circuit held that incinerator ash should be regulated as hazardous waste.[202] The City of Chicago an-

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[191] Hazardous Waste Management System; Final Codification Rule, 50 Fed. Reg. 28,725–26 (EPA 1985) (to be codified at 40 C.F.R. §§ 260, 261, 262, 264, 265, 266, 270, 271, 280) (proposed July 15, 1985).

[192] *Id.*

[193] *Demonstrators Protest EPA Proposal to Exempt Incinerator Ash from Tests*, 18 Env't Rep. (BNA) No. 34, at 1927 (Dec. 18, 1987).

[194] OTA Report, *supra* note 1, at 258.

[195] Environmental Defense Fund, Inc. v. Wheelabrator Technologies, Inc., 725 F. Supp. 758 (S.D.N.Y. 1989), *aff'd*, 931 F.2d 211 (2nd Cir.), *cert. denied*, 112 S. Ct. 453 (1991).

[196] Environmental Defense Fund, Inc. v. City of Chicago, 727 F. Supp. 419 (N.D. Ill. 1989).

[197] *Id.* at 424.

[198] *City Incinerators—Court Exempts Ash from Regulation*, ENVTL. POL'Y ALERT, Dec. 13, 1989, at 19; *Ash from Municipal Incinerators Excluded from RCRA Regulations, Federal Court Says*, 20 Env't Rep. (BNA) No. 31, at 1347 (Dec. 1, 1989).

[199] EDF v. Wheelabrator Technologies, Inc., 931 F.2d 211 (2d Cir. 1991).

[200] *Id.* at 213.

[201] EDF v. Wheelabrator Technologies, *cert. denied*, 112 S. Ct. 453 (1991); *High Court Says It Will Not Review Dispute Over Regulation of Hazardous Incinerator Ash*, 22 Env't Rep. (BNA) No. 30, at 1791 (Nov. 22, 1991).

[202] Environmental Defense Fund, Inc. v. City of Chicago, 948 F.2d 345 (7th Cir. 1991), *cert.*

nounced that it would appeal to the U.S. Supreme Court.[203] It filed a petition for review on February 18, 1992.[204] This issue was not resolved by the CAA Amendments. The Senate's CAA Amendments (S. 1630) allowed incinerator ash to be treated as non-hazardous waste.[205] In the House of Representatives, the subject was considered by the Energy & Commerce Subcommittee on Transportation and Hazardous Material to be part of the RCRA amendments (H.R. 2162).[206] EPA was under pressure to make a decision without waiting for Congress to act,[207] but it did not act. In March, 1990, an EPA-sponsored study determined that municipal ash was not hazardous;[208] however, that study was immediately attacked by those on both sides of the issue because the study found that ash flunked EPA's hazardous waste test, even though ash leachate was close to drinking water standards.[209] Congress should have acted to resolve this issue but it did not.[210] The CAA Amendments of 1990 instructed EPA not to regulate ash from MSW incineration pursuant to section 3001 of RCRA for a two-year period after which the CAA moratorium should not be construed to affect any action the Administrator of EPA may take.[211] Resolution of the ash issue was expected to come in the RCRA reauthorization legislation. Both the Senate and the House reauthorization bills, S. 976 and H.R. 3865, provide for ash to be managed more stringently than under existing law, but without imposing RCRA Subtitle C hazardous waste requirements.[212] But as 1992 ended, RCRA

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*granted and judgment vacated*, 113 S. Ct. 486 (1992), *on remand*, 985 F.2d 303 (1992), *cert. granted*, 113 S. Ct. 2992 (1993). For further discussion, see *infra* notes 219–22 and accompanying text.

[203] *Court Decision on Ash Conflicts with Earlier Ruling, Placing Onus on Congress*, INSIDE EPA, Nov. 29, 1991, at 1.

[204] *Ruling on Chicago's Municipal Incinerator Ash Should Be Reviewed By Supreme Court, City Says*, 24 Env't Rep. (BNA) No. 44, at 2438 (Feb. 28, 1992).

[205] *Senate Clean Air Legislation Includes Ash Management, Recycling for Incinerators*, 20 Env't Rep. (BNA) No. 49, at 1932 (Apr. 6, 1990).

[206] *Municipal Incinerator Ash Bill: H.R. 2162; Action: House Panel Considers Toxicity*, ENVTL. POL'Y ALERT, May 31, 1989, at 16.

[207] *Reilly Asked to Make Major Policy Call on Whether Municipal Ash Is Hazardous*, INSIDE EPA, May 12, 1989, at 16.

[208] *Significant New EPA Study Finds Waste Incinerator Ash Not Hazardous*, INSIDE EPA, Mar. 23, 1990, at 1; *Waste Ash—EPA Study May Show No Health Hazards*, ENVTL. POL'Y ALERT, Apr. 4, 1990, at 21; *Tests Used On Incinerator Ash May Overpredict Presence of Hazardous Elements, EPA Study Says*, 20 Env't Rep. (BNA) No. 48, at 1909 (Mar. 30, 1990).

[209] *Scientists Join Industry in Criticizing EPA "Misrepresentation" of Ash Study*, INSIDE EPA, June 22, 1990, at 10.

[210] *See Hazardous or Not, Interest Groups Want Incinerator Ash Legislation from Congress*, 20 Env't Rep. (BNA) No. 39, at 1650 (Jan. 26, 1990).

[211] 42 U.S.C. § 6921 (Supp. II 1990).

[212] *Court Decision on Ash Conflicts with Earlier Ruling, Placing Onus on Congress*, INSIDE EPA, Nov. 29, 1991, at 1.

reauthorization had not occurred. As a result, because the decision to select an incinerator option is heavily influenced by the costs of ash disposal, CAA Amendments section 306 discouraged the use of MSW incinerators.[213]

Labeling MSW incinerator ash as hazardous waste has major economic implications for industry and for municipalities that own or utilize MSW incinerators. Stringent regulations governing the transport, storage, treatment, and disposal of hazardous waste make such wastes more expensive to manage than non-hazardous waste.[214] Should MSW incinerator ash fall under the legal constraints of hazardous waste, the economic advantages of MSW incineration over other MSW management options could be severely reduced or even eliminated.[215]

Thus, the economic consequences of classifying MSW incinerator ash as hazardous waste significantly affects the decision to use an incinerator. The tipping fees, which are the charges imposed for dumping ash at landfills, would increase substantially if incinerator ash had to be treated as hazardous waste.

An interesting issue is the legal status of incinerator ash dumped in a land facility even if the ash is deemed non-hazardous under RCRA. If the landfill leaks in the future, CERCLA liability may attach to any generator who sent material that included any hazardous substance.[216] Since CERCLA's universe of hazardous *substances* is larger than the RCRA universe of hazardous *waste*, and since RCRA exempts many hazardous substances from its full hazardous waste regulatory program, a person exempt under RCRA cannot be

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[213] *See infra* notes 235–41 and accompanying text.

[214] *See infra* III.C.4.

[215] RCRA classifies solid waste as hazardous if it is on an EPA list, 40 C.F.R. § 266.30 (1990), or if the waste has hazardous characteristics. 42 U.S.C. § 6921; Identification and Listing of Hazardous Waste, 40 C.F.R. § 261 (1992). Only about ten percent of the hazardous waste generated in 1985 was "listed" waste but 56 percent was hazardous by "characteristic" only. The remainder of the waste was a mix. The characteristic test usually lists a waste as hazardous because of its ability to leach certain substances that might lead to violation of drinking water standards. Such a test is overinclusive since it regulates waste that may never be subject to leaching processes, but it is underinclusive because it fails to deal with air emissions or other ecological harm not related to drinking water.

Because the costs of hazardous waste disposal are high in relation to other waste disposal, there is pressure to exempt sources that could otherwise be considered hazardous. Household wastes, medical wastes, mining wastes, petroleum wastes, used oil, utility wastes, and wastes from small generators are excluded. More hazardous waste is excluded from regulation than is included. Pedersen, *supra* note 3, at 118–20.

[216] Amoco Oil Co. v. Borden, Inc., 889 F.2d 664 (5th Cir. 1990); United States v. Western Processing, Inc., 734 F. Supp. 930 (W.D. Wash. 1990).

certain of also being exempt from CERCLA-based liability in the future.

The ramifications of treating ash as hazardous waste may also be seen as shifting the priority determinations regarding the other levels in the MSW management hierarchy. If MSW incinerator ash were classified as hazardous, *arguendo*, the other options—such as source reduction and recycling, which offer better environmental protection—would become increasingly attractive to industry from a purely economic standpoint. Whether the concomitant environmental improvement would justify the cost to industry remains questionable.

However, these other options of managing MSW should not be considered as solely separate and distinct from the incineration option. Rather, source reduction and recycling can complement MSW incineration by not only reducing the amount of MSW, but, by targeting specific items such as batteries that contain toxics, they can also reduce or even eliminate the creation of hazardous ash.[217]

In a memorandum to Regional Administrators on September 18, 1992, EPA Administrator William Reilly announced a new policy based on RCRA section 3001(i) that ash generated from burning non-hazardous MSW at resource recovery facilities or MWCs is non-hazardous waste regulated under RCRA Subtitle C.[218] This policy was prompted by a U.S. Supreme Court request for a federal government interpretation of RCRA's ash provisions as the Court was reviewing the City of Chicago's petition for certiorari that was subsequently granted.[219]

On November 16, 1992, the U.S. Supreme Court in *Chicago v. Environmental Defense Fund* vacated a ruling by the U.S. Court of Appeals for the Seventh Circuit that required incinerator ash to be considered hazardous waste if it failed an EPA toxicity test. The case was remanded to the Seventh Circuit to make a new decision.[220] In November, 1992, the U.S. Supreme Court rejected an appeal and sent the case back to the Seventh Circuit.[221] On January 12, 1993, the

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[217] *See infra* notes 292–300 and accompanying text.

[218] *EPA Rules Garbage Incinerator Ash Non-Hazardous In Major New Policy*, INSIDE EPA, Sept. 25, 1992, at 8.

[219] Chicago v. EDF, 113 S. Ct. 486 (1992).

[220] *Supreme Court Bows to EPA, Rejects Hazardous Waste Call for Incinerator Ash*, INSIDE EPA, Nov. 20, 1992, at 1; *see also Supreme Court Vacates Appellate Ruling on Incinerator Ash from Chicago Facility*, 23 Env't Rep. (BNA) No. 30, at 1859 (Nov. 20, 1992).

[221] The case first came to the 7th Circuit in 1991 as *EDF, Inc. v. Chicago*, 948 F.2d 345 (7th Cir. 1991). Following this decision it went to the Supreme Court as *Chicago v. EDF*, 112 S. Ct. 1932 (1992). Then, in *Chicago v. EDF*, 113 S. Ct. 486 (1992), the case was vacated and remanded. See *also Supreme Court Bows to EPA, Rejects Hazardous Waste Call for Incinerator Ash*, INSIDE EPA, Nov. 20, 1992, at 1.

Seventh Circuit reaffirmed its previous holding that municipal waste combustion ash should be classified as hazardous waste if it fails EPA's toxicity test.[222] Finally, on June 21, 1993, the U.S. Supreme Court agreed to face, for the second time, the issue of whether ash generated by a MSW incinerator is subject to RCRA regulation if it exhibits hazardous characteristics.[223]

2. The 1989 Proposed Guidelines

The EPA proposed control guidelines for emissions from existing and new MSW incinerators on December 20, 1989.[224] The guidelines for existing MSW incinerators were to implement CAA section 111(d)[225] based on the "Administrator's determination that MWC emissions cause, or contribute significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare."[226] MSW incinerators were not regulated under CAA section 112 because the emissions were not considered hazardous as that term is used in that section. MSW incinerators were not regulated under CAA sections 108–110 because the emissions are not emitted from "numerous or diverse" sources as required by section 108. When final section 111(d) guidelines were promulgated, the states would have nine months to submit a plan using procedures similar to those for submitting implementation plans under section 110. These EPA guidelines specified the best system of emission reduction that the states were required to include in their plans. The states could impose more stringent standards, based on CAA section 116,[227] because EPA guidelines, which require the consideration of costs, non-air quality health and environmental impacts, and energy requirements, are limited in stringency.

The EPA follows a protocol for developing emission guidelines for existing sources. The elements generally are:

1. identification of the sources to be regulated;
2. definition of the equipment that comprise the sources to which the guidelines apply;

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[222] *Court Rejection of EPA Ash Policy Forces Issue Back to Supreme Court*, INSIDE EPA, Jan. 22, 1993, at 13. The January 12th case is the decision on remand but it was released as an unpublished order. On January 29, 1993 the 7th Circuit subsequently decided to release the case as a published opinion *EDF, Inc. v. City of Chicago*, 985 F.2d 303 (7th Cir. 1993).

[223] *U.S. Supreme Court Agrees to Review RCRA Applications to City Incinerator Ash*, 24 Env't Rep. (BNA) No. 8, at 342 (June 25, 1993).

[224] 54 Fed. Reg. 52,209, *supra* note 10.

[225] 42 U.S.C. § 7411.

[226] 54 Fed. Reg. 52,209, *supra* note 10.

[227] 42 U.S.C. § 7416.

3. identification of the substances emitted by the facility that the guidelines control;
4. identification of "best demonstrated technology" (BDT);
5. selection of the format for the guidelines—emission limits, percentage reduction, pollutant concentration, equipment or work practice requirements;
6. development of actual guidelines—usually emission limits based on BDT; and
7. other guidelines for visible emissions, modification/reconstruction provisions, monitoring requirements, performance test methods and compliance procedures, and reporting and record-keeping requirements.[228]

The major limitation on emissions would be the best demonstrated technology (BDT) as discussed below.[229]

For regulatory purposes, MSW incinerator emissions can be placed in three classes: organics, metals, and acid gases. Organics are regulated by limits on dioxin/furan emissions and by operational guidelines for CO, load limits, flue gas temperature limitations, and MWC operator training. Metals are controlled by limits on particulate matter (PM) because trace metals condense on PM. Acid gases are controlled by emission limits on sulfur dioxide ($SO_2$) and hydrogen chloride (HCl).

### 3. Best Demonstrated Technology

The 1989 proposed guidelines divided MWC plants into three size categories with increasing stringency of air pollution controls being required.[230] Small plants were those that combusted up to 250 tons per day; large plants were those that combusted up to 2,200 tons per day; and regional plants were those burning more than 2,200 tons per day. In the 1991 guidelines, the definitions changed so that large plants are those between 250 tons per day and 1,100 tons per day while very large plants are those greater than 1,100 tons per day.[231] For small MSW incinerators, organics (dioxins/furans) were to be controlled by restricting the allowable emissions to 500 nanograms per normal cubic meter ($ng/Nm^3$) or 200 grains/billion dscf for total tetra- through octa-chlorinated dibenzo-p-dioxins and dibenzofurans. To control metals, particulate emission limits were established. They were based on

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[228] 54 Fed. Reg. 52,209, *supra* note 10.

[229] *Id.* at 52,211.

[230] *Id.* at 52,216.

[231] 56 Fed. Reg. 5514, 5522 (EPA 1991) (to be codified at 40 C.F.R. §§ 51, 52, 60) (proposed Feb. 11, 1991).

electrostatic precipitators (ESPs). The proposed limits were sixty-nine milligrams per dry standard cubic meter (mg/dscm) or 0.030 gr/dscf. BDT for small MSW incinerators included good combustion practices for control of organics and an ESP to control metals and particulate matter.

In large MWC plants, organics were to be controlled to 125 ng/Nm$^3$ (fifty gr/billion dscf); however, those plants burning refuse-derived fuel (RDF) could emit 250 ng/Nm$^3$ (one hundred gr/billion dscf). Particulate controls were 69 mg/dscm (0.030 gr/dscf). Acid gas controls, which were not imposed on small MSW incinerators, required a fifty percent emission reduction or twenty-five parts per million by volume (ppmv) of HCl and a fifty percent reduction or thirty ppmv for $SO_2$ for large plants. BDT for these plants was to include good combustion practices for organics control and dry sorbant injection followed by the use of an ESP or a fabric filter to control metals, particulate matter, and acid gases. Additionally, BDT was to provide further control of organics.

Regional MSW incineration plants would have had an organics limit between five and thirty ng/Nm$^3$ (two to twelve gr/billion dscf), with the precise number to be chosen later by EPA. Particulates were to be controlled to thirty-four mg/dscm (0.015 gr/dscf). HCl was to be reduced ninety-five percent or to twenty-five ppmv, and $SO_2$ was required to be reduced eighty-five percent or to thirty ppmv. This was to be achieved first by good combustion practices to control organics, and then by a spray dryer and a fabric filter to control organics, metals and particulates, and acid gas.

In addition, all MSW incinerators would have been required to reduce the weight in their MSW inputs by twenty-five percent or more. Only ten percent of this reduction could come from yard waste. Furthermore, lead-acid vehicle batteries weighing over five kg (eleven lbs.) could not be burned, and a program was to be established to remove household batteries prior to combustion. Opacity controls for particulates would also have been required. These waste reduction rules were controversial as they threatened the ability of small incinerators to use BDT.[232]

Good combustion practices would have required the following: compliance with carbon monoxide levels in exhaust gas, maximum load limits for each facility, and temperature controls at the particulate

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[232] *Small Business Association Blasts EPA's Proposed Incinerator Reg as Contrary to Solid Waste Strategy*, INSIDE EPA, Apr. 27, 1990, at 10. *See Source Separation for Incinerators Conflicts with Federal Law, Groups Say*, 20 Env't Rep. (BNA) No. 50, at 1960 (Apr. 13, 1990).

control matter device inlet to ensure the gases remain below 230°C (450°F) to minimize dioxin/furan formation. The requisite controls would have varied according to the technology of the MWC.

Under the 1989 proposed guidelines, MWC organic emissions were to be tested annually. After three successful years of tests for dioxin/furan, the tests could have been skipped for two years but had to be done at least every three years. Particulate matter testing to ensure control of metals was to be based on a similar sequence—at least every three years. Acid gas would be determined by using a continuous monitoring system. Testing and data gathering requirements would have been determined later by EPA. At a minimum, each large or regional MSW plant would have required testing every three years for acid gas emissions. Since the passage of the CAA Amendments of 1990, the issue has been raised as to whether recycling must be evaluated as part of BACT technology. The Court of Appeals for the Ninth Circuit held that recycling did not have to be considered.[233] But, EPA, in 1992, ruled that separation of municipal wastes must be evaluated as BACT for preconstruction permits involving waste-to-energy facilities under the CAA.[234]

4. Impacts of Guidelines

Based on the 1989 proposed guidelines, MSW incinerators' dioxin/furan emissions would have decreased over ninety percent. Metal emissions would have been reduced approximately ninety-seven percent for all metals except mercury. Acid gases, $SO_2$ and HCl, would have been reduced over fifty percent from a baseline of unregulated emissions. No significant water pollution would have occurred because no wastewater is produced by these controls. The requirements would not have materially affected the solid waste created by incinerators, though the net amount of ash created would increase about three percent due to the use of sorbent material for air pollution control. A small amount of energy would have been required—nationally about 73,000 megawatt hours of electricity per year. Waste-to-energy generating plants would have incurred a net reduction in energy production of 2.6 percent. The costs of control on a national average would have been approximately $9.90 per ton of MSW combusted. For

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[233] Citizens for Clean Air v. EPA, 959 F.2d 839, 848 (9th Cir. 1992).

[234] *Brooklyn Navy Yard Resource Recovery Facility*, PSD Appeal No. 88-10 (Feb. 28, 1992) (cited in Michael H. Levin, *"Fuel Cleaning" and Materials Separation at Waste-to-Energy Plants*, 42 J. AIR & WASTE MGMT. ASS'N 767 (1992)).

large and regional plants, costs would have ranged from $4 to $14 per ton of MSW combusted.

### *D. The 1990 CAA Amendments*

The pre-1990 CAA requirements imposed on MSW incinerators, discussed above, did not generally represent the degree of protection that could be achieved by a vigorous application of a best available technology standard. Existing incinerators were subject primarily to state regulations which have varied considerably in stringency. In addition, the threshold size for regulation often resulted in having smaller incinerators which served apartments and commercial buildings regulated even less effectively than MSW incinerators.

The pre-1990 air pollution controls for MSW incinerators were so weak that considerable public distrust developed. This distrust will be difficult to overcome.[235] Hazardous waste facilities, which have been regulated more stringently under RCRA, are also opposed by the public.[236]

The CAA Amendments of 1990 created a new CAA section 129 dealing with solid waste combustion.[237] Subsection (a)(1) requires the Administrator to establish performance standards for categories of solid waste incineration units under sections 111 and 129. The standards should include emission limitations for new units and guidelines under section 111(d) applicable to existing units.[238] Under this provision and under the new source performance standards of CAA section 111, EPA is to regulate MSW incinerators with greater than 250 tons per day input by November 15, 1991. Standards for MSW incinerators with a capacity equal to or less than 250 tons per day must be adopted

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[235] The legal weaknesses of trying to regulate an MSW incinerator under the pre-1990 law are discussed in an excellent article by Professor Karen D. Kendrick-Hands, *The Clean Air Act Amendments of 1990: New Standards for Municipal Solid Waste Incineration and Detroit's Resource Recovery Facility*, 1991 DET. C.L. REV. 1 (1991).

[236] Air pollution from hazardous waste incinerators is controlled primarily by 40 C.F.R. §§ 264.340-264.351 (1992). Proposals to tighten standards are found at 54 Fed. Reg. 45,311 (1989) and 55 Fed. Reg. 17,862 (1990).

[237] 42 U.S.C. § 7429 (Supp. II 1990).

[238] Clean Air Act Amendments, Pub. L. No. 101-549, § 305, 104 Stat. 2399, 2577-84 (1990). Until finally enacted, it was not clear that the new law would have specific incinerator provisions. The House bill contained no incinerator related measures, the Senate bill did. It was opposed by House members who believed the subject should be dealt with in the RCRA reauthorization. *Members Urge Incinerator Measures with Exemptions Be Stripped From CAA*, INSIDE EPA, Aug. 17, 1990, at 14.

Environmentalists also opposed the incinerator provisions of the CAA Amendments. *States Say Senate Incinerator Plan Is Needed to Head Off Solid Waste Crisis*, INSIDE EPA, Aug. 31, 1990, at 14.

by November 15, 1992.[239] Standards for MSW incinerators combusting commercial or industrial waste, which if combined with MSW can legally be MSW, must be proposed by November 15, 1993 and adopted by November 15, 1994.[240] EPA must also publish a schedule for the promulgation of standards applicable to other categories of solid waste incineration units within eighteen months.[241]

Standards applicable to MSW incinerators are to reflect the maximum degree of emission reduction after considering costs, non-air quality health and environmental impacts, and energy requirements. The Administrator may distinguish among classes, types (including mass burn, refuse-derived fuel, modular, and other types of units), and sizes, but emission standards shall not be less stringent than the best controlled similar unit. Existing units may be less stringently controlled than new units, but cannot be less stringent than the average of the best performing twelve percent of the units in the regulated category.[242]

The statute also requires numerical emission limitations for the following: particulate matter (PM) (total and fine), opacity, sulfur dioxide ($SO_2$), hydrogen chloride (HCl), oxides of nitrogen ($NO_x$), carbon monoxide (CO), lead (Pb), cadmium (Cd), mercury (Hg), dioxins and dibenzofurans.[243] The Administrator may also regulate other substances either by emission limitations or by requiring other techniques. The Administrator may promulgate numerical emission limits or may provide for the monitoring of post-combustion concentrations of surrogate substances, parameters or periods of residence time in excess of stated temperatures for the control of other pollutants.[244]

For existing units, EPA will promulgate guidelines issued under CAA section 111(d), and the states will submit to EPA their plans implementing the guidelines within three years after the plans are approved, but not later than five years after the guidelines were promulgated.[245] If the state fails to develop a plan, the Administrator will develop a federal plan.[246] Guidelines for MSW incinerators with capacities greater than 250 tons per day were issued on February 11, 1991.[247] For MSW incinerators less than or equal to 250 tons per day,

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[239] 42 U.S.C. § 7429(a)(1)(C) (Supp. II 1990).
[240] 42 U.S.C. § 7429(a)(1)(D) (Supp. II 1990).
[241] 42 U.S.C. § 7429(a)(1)(E) (Supp. II 1990).
[242] 42 U.S.C. § 7429(a)(2) (Supp. II 1990).
[243] *Id.*
[244] *Id.*
[245] 42 U.S.C. § 7429(b)(2) (Supp. II 1990).
[246] 42 U.S.C. § 7429(b)(3) (Supp. II 1990).
[247] 56 Fed. Reg. 5514, *supra* note 231.

guidelines must be promulgated by November 15, 1992.[248] The guidelines divide plants over 250 tons per day into two categories; namely, those over 1,100 tons per day and those from 250 tons per day to 1,100 tons per day. Plants in this latter category are termed "very large." To date, there are forty-five very large MSW incinerators.[249]

The Administrator must require appropriate monitoring of emissions and operating parameters. The results of monitoring must be available to the public.[250] By November 15, 1992, the Administrator is required to develop a model state program for the training and certification of solid waste incinerator operators. Training is a prerequisite to lawfully operating an incinerator.[251]

Beginning thirty-six months after promulgation of performance standards under sections 129(a) and 111, each unit is required to have a permit issued under both section 129 and subchapter V of the CAA.[252] Permits must be issued for up to twelve years, but they are renewable every five years after public comment and a public hearing.[253] The term "Solid Waste Incineration Unit" is defined to exclude the following: hazardous waste incinerators; materials recovery facilities that recover metals; qualifying small power production facilities; and qualifying cogeneration facilities that burn homogeneous fuel such as tires or waste oil. The term includes, however, those units that burn RDF.[254] Air curtain incinerators that burn only wood wastes, yard wastes, or clean lumber are also excluded.[255] New and modified incineration units are subject to the more stringent standards. Modified units are those with modifications that extend the life of the unit and that exceed fifty percent of the original cost of the unit (not including land), or those that make a physical change in the unit or a change in the method of operation which increases the air pollution of any pollutant regulated by sections 129 or 111.[256] Municipal waste is defined in the CAA,[257] and based on this definition an MSW facility must combust more than thirty percent municipal waste by weight of its fuel feed.[258]

If the incinerator burns eighty percent or more of its fuel measured

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[248] 42 U.S.C. § 7429 (Supp. II 1990).
[249] 56 Fed. Reg. 5522, *supra* note 231.
[250] 42 U.S.C. § 7429(c) (Supp. II 1990).
[251] 42 U.S.C. § 7429(d) (Supp. II 1990).
[252] 42 U.S.C. § 7429(e) (Supp. II 1990).
[253] *Id.*
[254] 42 U.S.C. § 7429(g) (Supp. II 1990).
[255] *Id.*
[256] 42 U.S.C. § 7429(g)(3) (Supp. II 1990).
[257] *See* 42 U.S.C. § 7429(g)(5) (Supp. II 1990).
[258] *Id.*

on a BTU basis that is solid waste, it shall not be regulated as a utility under CAA subchapter IV.[259] Under the CAA section 129(h), the states are free to regulate solid waste incinerators more stringently than required by the CAA.

While the new CAA section 129 provides for a regulatory program specifically for MSW incinerators, the overall air pollution control program will also affect such units. MSW incinerators can produce all of the criteria pollutants (including ozone indirectly through release of nitrogen oxides and hydrocarbons). Changes in the overall ambient air programs may affect incinerator placement. Of particular importance will be the new requirements for nonattainment areas. The 1990 CAA Amendments create a new program for nonattainment areas with more stringent requirements being imposed in these dirty areas.[260] Nonattainment areas are ranked in order of increasing pollution as marginal, moderate, serious, severe, and extreme, with the tightest controls on the most polluted areas.

A solid waste incinerator regulated under CAA sections 111 and 129 is not to be regulated under the hazardous air pollutants provision of section 112(d)(2).[261] The incineration unit controls approved by section 129 are tied to the hazardous waste provisions of CAA section 112, including new provisions to protect public health and the environment in section 112(f).[262] But section 112(h)(3) makes standards under section 129 the standards under section 112(d)(2) and limits the pollutants that may be regulated to those listed in section 129(a)(4).[263] MSW incinerators will be controlled by regulations promulgated under section 111 and 129, not as hazardous air pollutants (NESHAPs) under section 112. There are also provisions applicable to modifications of facilities that require offsets,[264] with special limitations on the use of offsets for emissions of high risk pollutants such as chlorinated dioxins and furans.[265] In addition, a qualifying resource recovery facility may be able to defer providing offsets and use offsets that become available in the future to cover its requirements.[266]

In summary, under the 1990 CAA Amendments a MSW incinerator must meet the following:

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[259] 42 U.S.C. § 7429(h)(4) (Supp. II 1990).

[260] 42 U.S.C. § 7429; Clean Air Amendments, Pub. L. No. 101-549, § 103, 104 Stat. 2399, 2423-52 (1990) (*creating* CAA §§ 181–185, 42 U.S.C. §§ 7511-11(f) (Supp. II 1990)).

[261] 42 U.S.C. § 7429(h)(3) (Supp. II 1990).

[262] *See id.*

[263] 42 U.S.C. § 7429(g) (Supp. II 1990).

[264] 42 U.S.C. § 7412(g) (Supp. II 1990).

[265] 42 U.S.C. § 7412(i)(5)(E) (Supp. II 1990).

[266] Emission Offset Interpretive Ruling, 40 C.F.R. § 51, App. S, III B (1992).

1. requirements applicable to new or existing sources under sections 111 and 129;
2. requirements imposed in clean areas, Prevention of Significant Deterioration (PSD), to include Best Available Control Technology (BACT) for new sources;[267]
3. requirements imposed for nonattainment areas including Lowest Achievable Emission Rate (LAER) for new sources and Reasonably Available Control Technology (RACT) for existing sources;[268] and
4. more stringent controls imposed by state law.

### *E. The 1991 CAA Regulations*

The 1990 CAA Amendments require new regulatory efforts directed at solid waste incinerators, including MSW incinerators.[269] However, EPA was already subject to the consent decree in *State of New York v. Reilly*[270] that required standards to be promulgated for combustion units greater than 250 tons per day. Section 129 has a savings clause authorizing EPA to issue standards as required by the consent decree.[271] EPA had proposed standards on December 20, 1989 that have been discussed above.[272]

Final standards were due December 31, 1990, but the court extended the deadline until January 11, 1991. The final rule was published in the Federal Register on February 11, 1991.[273] Minor changes were made in the proposed rule to conform to the new CAA section 129 requirements, but the Amendments gave EPA one year to revise the standards for large MSW incinerators to conform fully to section 129. This will require the addition of numerical emission limits for mercury, cadmium, and lead.[274] EPA must also regulate MSW incinerators of 250 tons per day or less capacity within two years.[275] Emission guidelines to be used by states in developing regulations for existing facilities were also promulgated.[276]

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[267] For incinerators, the toxic requirements may preclude the application of additional PSD requirements because of revised § 112(b)(6). *See* 56 Fed. Reg. 5502, *supra* note 129.

[268] Legislation was introduced by Rep. Peter Kostamayer (D-Pa.) as part of the RCRA reauthorization that would ban new or modified incinerators in EPA designated ozone nonattainment areas. *House Bill Would Ban Sites in Nonattainment Areas*, ENVTL. POL'Y ALERT, Aug. 21, 1991, at 3; *Municipal Landfills—Rule Would Give States Program Flexibility*, ENVTL. POL'Y ALERT, June 12, 1991, at 4.

[269] 42 U.S.C. § 7429 (Supp. II 1990).

[270] *See* 969 F.2d 1147, 1152 (D.C. Cir. 1992).

[271] 42 U.S.C. § 7429(a)(1)(B) (Supp. II 1990).

[272] 54 Fed. Reg. 52,251, *supra* note 10. *See supra* notes 224–34 and accompanying text.

[273] 56 Fed. Reg. 5488, *supra* note 129.

[274] *Id.*

[275] *Id.*

[276] 56 Fed. Reg. 5514, *supra* note 231.

The new rule will impact new units with the capacity to burn 250 tons or more of trash per day. There are thirty new plants with a total of seventy combustion units expected to be constructed by 1995 that will be subject to its provisions. The guidelines will require the states to regulate more stringently the one hundred existing MSW incinerators, each having two or three combustion units over 250 tons per day.[277] This was the first rule promulgated under the new CAA.

The final rule for new, modified or reconstructed MSW incinerators was based on CAA section 111(b). The emission guidelines for the states were based on CAA section 111(d). However, in the 1990 Amendments, CAA section 112 now requires technology-based standards for hazardous air pollutants,[278] and CAA section 129 directs EPA to issue technology-based standards for MSW incinerators under both sections 129 and 111.[279] Thus, this final regulation is based on more than one section of the CAA and establishes the best technological system of continuous emission reduction as defined in CAA section 111(a)(1). This standard is called Best Demonstrated Technology (BDT).[280]

The final regulation applies to any facility that combusts 250 tons per day or more of MSW by burning or pyrolysis with or without heat recovery.[281] BDT is specified as:

> (1) Good combustion practices (GCP) for [municipal waste combustors] MWC organics control, and (2) a spray dryer (SD) followed by a fabric filter (FF) to achieve additional control of MWC organics as well as MWC metals, and MWC acid gases.[282] The best technological basis for reducing $NO_x$ emissions from affected new MWCs is an emission limit based on application of selective noncatalytic reduction (SNCR) at a typical MWC.[283] The $NO_x$ emission level can be met by combustor design, the application of post-combustion control (such as SNCR) or a combination of the two.[284]
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> The proposed standard included the separation of recoverable materials prior to combustion as part of best demonstrated tech-

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[277] *EPA Rule Sets New Standard for Big Municipal Solid Waste Incinerators*, CLEAN AIR REP., Jan. 17, 1991, at 15.

[278] *See supra* notes 261–66 and accompanying text.

[279] 56 Fed. Reg. 5489, *supra* note 129.

[280] *Id.*

[281] The final regulation made minor changes in the definition of MSW including the exclusion for combustors burning less than 30 percent by weight of MSW as is required by the CAA Amendments. *Id.* at 5490.

[282] *Id.*

[283] *Id.*

[284] *Id.*

> nology for reducing emissions. Under the final standards, materials separation is not included as part of best demonstrated technology. The rationale for this change is described in § VIII.B of this notice.[285]

Good combustion practices also include mandatory operating parameters for carbon monoxide, combustor load level, and flue gas temperature limits.[286] The first two parameters are specified for each of the combustor technologies, but the temperature limits are site-specific based on the most recent dioxin/furan compliance test. The final standards require certification of the chief facility operator and the shift supervisor, but since CAA section 129 requires EPA to develop an MWC operator training and certification program within two years, these requirements will have to be updated at that time.[287] The final MWC organic standard is a dioxin/furan emission limit of thirty nanograms per dry standard cubic meter (dscm) at seven percent oxygen ($O_2$).[288] This is the high end of the proposed standard.[289] To control metals, there is a particulate emission limit of thirty-four milligrams per dry standard cubic meter (dscm) at seven percent oxygen ($O_2$) and an opacity limit of ten percent based on a six minute average.[290] Mercury, lead and cadmium emission limits were not established, but were required by regulation under CAA section 129(a)(4).[291] Proposals to require the separation of household batteries and lead-acid batteries were deleted from the final standards.[292] The reason for the deletion is that the battery industry has reduced the mercury content of alkaline batteries by over ninety percent since 1986, and further reductions are expected to occur.[293] Mercury oxide button cell batteries are thirty-five percent mercury, but there is no

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[285] *Id.*

[286] *Id.* at 5491.

[287] *Id.*

[288] *Id.*

[289] *Id.*

[290] *Id.*

[291] *Id.*

[292] *Id.*; EPA has also abandoned its efforts to require automotive battery recycling under the Toxic Substances Control Act (TSCA) claiming there is virtually no health risk. *EPA Abandons Effort to Mandate Auto Battery Recycling, Citing Low Risks*, INSIDE EPA, Sept. 20, 1991, at 1, 7.

[293] EPA reported that 709 tons of mercury were discarded as solid waste in 1989; mercury in household batteries accounted for 88 percent. Mercury in municipal waste is projected to decline 75 percent by the year 2000 because the battery industry is greatly reducing the mercury in alkaline batteries. Mercury levels are also expected to decrease as mercury-based biocides are phased out of paint. *Most Mercury in Land Fills from Batteries; Disposal Totaled 709 Tons in 1989, EPA Says*, 23 Env't Rep. (BNA) No. 18, at 1290 (Aug. 28, 1992).

known way to remove them from MSW effectively. They will, nevertheless, be indirectly controlled by the emission limits required for mercury by November 15, 1991 under CAA section 129.[294] Lead-acid battery removal was considered to be occurring already because of requirements imposed by section 3001(i) of RCRA, and further regulation was considered unnecessary.[295] The more general requirement for recycling through a mandatory twenty-five percent source separation requirement found in the proposed incinerator rule was dropped because of pressure exerted on EPA by then Vice President Quayle's Council on Competitiveness.[296] Environmentalists reacted with outrage, and the battle will probably continue during the RCRA reauthorization process.[297] The Natural Resources Defense Council (NRDC) and the states of New York and Florida brought a law suit against EPA in the U.S. Court of Appeals for the District of Columbia Circuit. They sought to reverse the lead-acid battery determination and to force EPA to reverse its decision to drop the twenty-five percent separation requirement for incinerators. They argued that EPA's reversal of its own findings was not a reasoned decision, as is required by the CAA and the Administrative Procedure Act (APA).[298] The exemption of lead-acid batteries from the regulation resulted in a remand on July 14, 1992, when the U.S. Court of Appeals for the District of Columbia Circuit held that EPA did not adequately explain why a ban on lead-acid batteries was not the best demonstrated technology.[299] Thus, the controversy continues. EPA won, however, on its decision to omit recycling provisions from the MSW incinerator rule.[300]

Acid gas limits are established for sulfur dioxide ($SO_2$) and hydrogen chloride (HCl).[301] There must be an eighty percent reduction in

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[294] A stringent mercury limit could force the shutdown of MSW incinerators. The absence of this provision in the 1991 regulation adds another area of uncertainty for anyone planning a new facility. *See Industry Fears EPA Limit for Incinerators Could Shut Down Many Units*, CLEAN AIR REP., Oct. 25, 1990, at 15.

[295] 56 Fed. Reg. 5499 (1991).

[296] *Defeat of EPA Trash Recycling Plan Harshly Criticized by Environmentalists*, INSIDE EPA, Jan. 4, 1991, at 3; *Quayle Council Recommends Killing Recycling Provision in Incinerator Rule*, 21 Env't Rep. (BNA) No. 35, at 1595 (Dec. 28, 1990); *Reilly Buckles Under White House Pressure to Dump Recycling Standards*, CLEAN AIR REP., Jan. 3, 1991, at 12.

[297] *Plaintiffs Argue EPA Ignored Own Expertise, Data in CAA Garbage Burner Regulation*, CLEAN AIR REP., Oct. 10, 1991, at 18.

[298] *See Environmentalists, States Sue EPA for Cutting Incinerator Reg Recycling Plan*, INSIDE EPA, Apr. 19, 1991, at 8, 9.

[299] New York v. Reilly, 969 F.2d 1147, 1150-53 (D.C. Cir. 1992).

[300] *Id.*

[301] 56 Fed. Reg. 5491, *supra* note 129.

$SO_2$ and a ninety-five percent reduction in HCl.[302] There is also a nitrogen oxide standard of 180 ppmv.[303]

Monitoring of incinerator operation has been strengthened. Continuous monitoring is required for CO level, MWC load level and flue gas temperature.[304] Dioxin/furans must be tested in compliance with Method 23 which was also promulgated in the February 11, 1991 Federal Register.[305] Particulate tests are specified to determine compliance with PM limits and must be performed annually.[306] Continuous monitoring of $SO_2$ and $NO_x$ is required.[307] HCl is to be monitored by Method 26 as promulgated in the February 11, 1991 Federal Register.[308] Reporting and record keeping requirements are mandated, and the records must be made available to the public.[309] EPA projects these standards to reduce dioxin/furan emissions by ninety-nine percent compared to uncontrolled emissions. For all metals except mercury, reductions of ninety-nine percent are projected. Acid gases will be approximately ninety-four percent controlled. $NO_x$ will be reduced about forty-five percent. There is no significant water pollution from MSW incineration, and solid waste is reduced approximately ninety percent by incineration.[310] The cost of the required controls will be nearly $11 per ton of MSW combusted. Typical costs of collecting, transporting, and combusting MSW, combined with disposing of the ash, now range from $36 to over $90 per ton. Assuming the full cost of the controls are passed on to MWC customers, increase in disposal costs will be in the twelve to thirty percent range.[311]

These new regulations demonstrate that environmentalists have been correct in their claims that state of the art incinerators could produce emissions far below what has commonly been required by state and federal law.[312] There are two levels of guidelines applicable to existing MSW incinerators of greater than 250 tons per day capacity. The most stringent limits apply to very large plants over 1,100 tons per day; less stringent standards apply to large plants—those

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[302] *Id.*
[303] *Id.*
[304] *Id.* at 5491-92.
[305] *Id.* at 5510.
[306] *Id.* at 5492.
[307] *Id.*
[308] *Id.*
[309] *Id.*
[310] *Id.* at 5493.
[311] *Id.*
[312] *Final Guidelines for Existing Sources to Halve Emissions at Municipal Incinerators*, 21 Env't Rep. (BNA) No. 42, at 1837 (Feb. 15, 1991).

above 250 tons per day but less than 1,100 tons per day.[313] For very large plants, dioxin/furan limits are sixty ng/dscm (twice as lenient as the new source standard) and a limit of 125 ng/dscm for large plants.[314]

Other requirements are similar to those imposed on new sources but are not as stringent. PM limits are thirty-four and sixty-nine mg/dscm for very large and large plants, respectively. $SO_2$ reductions must be seventy percent for very large plants and fifty percent for large plants; HCl reductions must be ninety percent for very large plants and fifty percent for large plants.[315] These new limits represent a substantial reduction in emissions if complied with, even though they only apply to the largest MSW incinerators. This is because this portion of the combustor universe deals with most of the wastes that are incinerated. The air pollutants that these regulations require removed still must go somewhere. The problem is that "somewhere" is increasingly difficult to find.

In May, 1990, the final rule on land disposal of over 450 RCRA regulated wastes was issued.[316] The RCRA regulations make land disposal of air pollutants captured by control equipment both difficult and costly.[317] While EPA's announced policy of September 18, 1992 is to treat MSW incinerator ash as non-hazardous, that position can be changed by Congress, the judiciary, or the EPA.[318]

Nonetheless, the key questions are whether these new regulations protect public health and whether facilities can be operated over an extended time period while still meeting the requirements. Moreover, if NIMBY issues are to be overcome, facilities not only must be operated to protect public health, but the public must believe they are being operated to that end. It is interesting to note that while environmentalists are greatly concerned with mercury emissions from incinerators, electric utilities are one of the major sources of mercury released to the air. Yet, electric utilities are not even required to report their toxic emissions under the Emergency Planning & Community Right-to-Know Act of 1986.[319] About thirty percent of the coal burned by electric utilities has a high mercury content, especially

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[313] 56 Fed. Reg. 5516, *supra* note 231.

[314] *Id.*

[315] *Id.*

[316] Julie C. Becker, *"The Least Favored Method"—A Primer on the RCRA Land Disposal Regulations*, 41 J. AIR WASTE MGMT. ASS'N 414 (Apr. 1991).

[317] *Id.*

[318] *See supra* note 218 and accompanying text.

[319] *Study Finds Utility Emissions Will Grow Absent Controls, Urges EPA Action*, INSIDE EPA, Dec. 6, 1991, at 15.

northern Appalachian bituminous coal, North Dakota lignite, and Texas lignite.[320] Thus, we must keep in mind that even harmful emissions from MSW incinerators need to be evaluated in terms of their relative health effects on the population.

Summary of 1991 MSW Incineration—Final Rules and Guidelines

| | New Source Performance Standards (NSPS) > 250 tons/day | Existing > 2,200 tons/day | Existing > 250 tons/day but ≤ 2200 tons/day |
|---|---|---|---|
| CO | 50 to 150 ppmv dependent upon the technology | 50 to 250 ppmv dependent upon the technology | 50 to 250 ppmv dependent upon the technology |
| Particulate Matter | 34 mg/dscm | 34 mg/dscm | 69 mg/dscm |
| Opacity | 10% | 10% | 10% |
| Organic Emissions (dioxins) | 30 ng/dscf | 60 ng/dscf | 125 ng/dscf |
| Acid Gas % reduction | | | |
| HCl | 95% | 90% | 50% |
| $SO_2$ | 80% | 70% | 50% |
| $NO_x$ | 180 ppmv | — | — |
| Temperature limit | site specific | — | — |

### *F. Health Risks Associated with MSW Incineration*

Incinerators that burn organics will not burn everything. The products of incomplete combustion (PICs) are among the most toxic pollutants found in stack gases of MSW incinerators. The major risks associated with MSW incinerators are from chlorinated dioxins (which are partially carried by PICs), cadmium, arsenic, and chromium.

The level of acceptable risk is not a subject on which there is much agreement. The effects of exposure to multiple pollutants, which include synergistic or antagonistic reaction among different compounds, and indirect pathways such as ingestion of food from crops exposed to air pollutants, have not been thoroughly studied. The risks of dioxin

[320] *Utilities Urged to Cut Mercury Emissions in Complying with Acid Rain Program Rules*, 22 Env't Rep. (BNA) No. 33, at 1974 (Dec. 13, 1991).

exposure are greater in magnitude than the risks for the heavy metals. It is estimated that dioxin has a maximum risk of producing one cancer case in every 1000 individuals exposed to MSW incinerator emissions for a lifetime.[321] Modern facilities using scrubbers can reduce this risk by an order of magnitude. EPA's Science Advisory Board considers these risk estimates to be too high, but considerable controversy surrounds this subject.[322] Making estimates is problematic in that data concerning lethality and decreased longevity following inhalation exposure of humans or animals to 2,3,7,8-TCDD is unavailable in the literature.[323]

In June, 1987, EPA issued a nine volume report to Congress that detailed the information that was available on municipal waste combustors (MWCs).[324] Included in the report was a study of the health risks from using MSW incinerators.[325] On July 7, 1987, EPA published an advance notice of proposed rulemaking (ANPRM) to regulate new and existing MSW incinerators under sections 111(b) and 111(d) of the CAA, respectively.[326] The Administrator determined that MSW incineration may reasonably be expected to contribute to the endangerment of public health and welfare. However, because of the uncertainties of estimating cancer risks, the Administrator did not list the emissions from MSW incinerators as hazardous air pollutants under the CAA section 112.[327]

The estimated health effects in the 1987 ANPRM were based on evaluations of health effects data for individual chemical constituents of MWC emissions. The information was combined with estimates of population exposure to determine the risks presented by MSW incinerator emissions.[328] There were no epidemiologic studies. Also, there were no direct human or animal studies of MSW incinerator impacts. EPA evaluated the impact of the criteria pollutants—particulate matter (PM), sulfur oxides ($SO_x$), carbon monoxide (CO), and nitrogen oxides ($NO_x$). These pollutants are produced in the amount of approximately 10,000 tons per year. The other hazardous pollutants are emitted in amounts measured as kilograms per year, except hydrogen

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[321] OTA Report, *supra* note 1, at 241.

[322] *Id. See also*, Washburn *et al.*, *supra* note 131.

[323] AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, U.S. PUBLIC HEALTH SERVICE, TOXICOLOGICAL PROFILE FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN 48 (1989).

[324] U.S. EPA, MUNICIPAL WASTE COMBUSTION STUDY (1991).

[325] U.S. EPA, ASSESSMENT OF HEALTH RISKS ASSOCIATED WITH MUNICIPAL WASTE COMBUSTION EMISSIONS (1987).

[326] 52 Fed. Reg. 25,399, *supra* note 54.

[327] 54 Fed. Reg. 52,209, *supra* note 10.

[328] 52 Fed. Reg. 25,403, *supra* note 54.

chloride. The criteria pollutants health effects are described in the relevant criteria documents.[329] Also reviewed were the health effects associated with inhalation exposure to lead and mercury emissions. The modeling results predicted no long term concentrations above the ambient lead standard of 1.5 ug/$m^3$ (quarterly average) or the mercury NESHAP ambient guidelines of one ug/$m^3$.[330]

EPA also reviewed the cancer risks associated with exposing the population continuously from birth throughout their lifetime to MSW incinerator emissions. EPA recognized that of all the PICs emitted, chlorinated dioxins and dibenzofurans would be the pollutants that resulted in most of the health risk from MSW incineration. For existing MSW incinerators, EPA projected two to forty excess cancer cases per year for the most exposed populations; the maximum risk was projected to range from $10^{-6}$ to $10^{-3}$ for the lifetime individual cancer risk. An estimate with a range of three orders of magnitude, however, does not provide much useful information. The risk of cancer in the most exposed populations from projected new MSW incinerators drops to 0.8 to 20 and the projected individual risk ranges from $10^{-6}$ to $10^{-4}$.[331] Both existing and projected facilities were assumed to have organics controlled by twenty percent. Particulates were assumed to be controlled to the levels required in 1987, and ninety-nine percent controls were assumed for projected facilities as required by the existing requirements for new construction.[332] The pollutants and their associated projected maximum individual risk ranges were:

| | |
|---|---|
| Chlorinated dioxins and dibenzofurans | $10^{-6}$ to $10^{-4}$ |
| Chlorophenols | $10^{-10}$ to $10^{-9}$ |
| Chlorobenzenes | $10^{-9}$ to $10^{-7}$ |
| Formaldehyde | $10^{-8}$ to $10^{-7}$ |
| Polycyclic aromatic hydrocarbons (PAHs) | $10^{-7}$ to $10^{-5}$ |
| Polychlorinated biphenyls (PCBs) | $10^{-9}$ to $10^{-6}$ |
| Arsenic | $10^{-8}$ to $10^{-7}$ |
| Berylium | $10^{-11}$ to $10^{-8}$ |
| Cadmium | $10^{-7}$ to $10^{-6}$ |
| Chromium | $10^{-7}$ to $10^{-6}$ |
| Total | $10^{-6}$ to $10^{-4}$ |

In 1989, EPA reviewed the cancer risk information in the 1987

[329] *Id.*
[330] *Id.*
[331] *Id.* at 25,404.
[332] *Id.* at 25,403.

ANPRM and concluded "that cancer risks for MWC's are likely at the lower end of the earlier estimated ranges cited in the ANPRM, although there remain significant uncertainties in the risk assessment."[333] Based on this data, most of the risk from MSW incinerators is the risk of exposure to chlorinated dioxins and dibenzofurans (CDD/CDF). The rest of the pollutants have such low risk that they do not materially affect the overall risk. The question then is whether CDD/CDF emissions can be effectively and reliably controlled to produce de minimis risk.

In 1989, the National Institute for Occupational Safety and Health published the results of an epidemiological study of data on 192 chemical workers exposed to dioxin over the past forty years at twelve plants. The study found no increased cancer risk among 3,500 workers with average dioxin levels ninety times greater than normal. The study found only a slight excess cancer risk among those exposed to the highest levels—those registering 500 times what is normal.[334] The study concluded that occupational exposure to TCDD does not confirm the high relative risks reported for many cancers in previous studies.[335] It seemed possible that this study might lead to a relaxation in dioxin regulation by EPA.[336]

In October, 1990, thirty-eight of the world's leading authorities on dioxin met in Long Island, New York at the "Banbury Conference" to examine the scientific data concerning human risks from dioxin.[337] They concluded that the linear model used in the United States is not accurate. A linear model assumes any exposure creates a risk. Instead, they endorsed a receptor-based model that allows for the presence of dioxin in the environment, with no biologically significant risk below a threshold level. This represents an evolution of expert thinking to a conclusion that dioxin effects are receptor-mediated, and therefore several thousand receptors must be occupied before a toxic effect can be observed.[338] On April 8, 1991, the EPA Administrator

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[333] 54 Fed. Reg. 52,219, *supra* note 10.

[334] Malcolm Gladwell, *Extensive Study Finds Reduced Dioxin Danger*, WASH. POST, Jan. 24, 1991, at A3.

[335] Fingerhut *et al.*, *Cancer Mortality in Workers Exposed to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin*, 324 NEW ENG. J. MED. 212 (1991).

[336] *Scientists Concur 'Safe' Dioxin Level Possible, Opening Door for Relaxed Regs*, INSIDE EPA, Jan. 25, 1991, at 1, 6; *EPA Likely to Upgrade Dioxin Cancer Classification to Reflect New Human Data*, INSIDE EPA, Feb. 1, 1991, at 4.

[337] *Conference Reassesses Human Risk from Dioxin Exposure*, 41 J. AIR WASTE MGMT. ASS'N 323 (1991).

[338] *Id.*

ordered a complete reevaluation of the risks associated with dioxin exposure and EPA's related regulations.[339] In late 1992, EPA was reassessing dioxin science in the Agency's Office of Research and Development.[340]

### *G. EPA's Reassessment of the Dioxin Risk*

It is apparent that one of the key issues surrounding the evaluation of the incineration option concerns the assessment of the dioxin risk. Because of the historical uncertainty surrounding the dioxin risk, any decision on the role of MSW incineration must, therefore, include a detailed evaluation of the effects of dioxin on human health and the environment.

Historically, the information concerning dioxin effects has been sparse and inconclusive. In EPA's "Health Assessment Document for Polychlorinated Dibenzo-p-Dioxins,"[341] the majority of the epidemiology studies pertained to groups of herbicide applicators with potential exposure to phenoxy acids and/or chlorophenols. The report concluded that the epidemiologic research available at the time provided limited evidence for the carcinogenicity of these compounds in humans, and that "with respect to the dioxin impurities contained therein, the evidence for human carcinogenicity for 2,3,7,8-TCDD based on the epidemiologic studies is only suggestive. . . ."[342] In its next report, the review draft of "A Cancer Risk-Specific Dose Estimate for 2,3,7,8-TCDD,"[343] the focus was essentially the same and EPA concluded that "the human evidence supporting an association between exposure to 2,3,7,8-TCDD and cancer is considered inadequate."[344]

In April, 1991, EPA Administrator William Reilly announced that EPA would conduct a scientific reassessment of the risks of exposure to 2,3,7,8-TCDD as well as chemically similar compounds, all collec-

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[339] David S. Baker & Douglas W. Smith, *Science Meets Policy—Dioxin Regulations in Flux*, ENVTL. L. (ABA), Summer, 1991, at 4.

[340] *Dioxin Guidance To Program Offices Urges Officials To Continue As Planned*, 22 Env't Rep. (BNA) No. 20, at 1293 (Sept. 13, 1991).

[341] U.S. EPA, OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT, HEALTH ASSESSMENT DOCUMENT FOR POLYCHLORINATED DIBENZO-P-DIOXINS, FINAL REPORT (1985).

[342] *Id.* at 11–108.

[343] U.S. EPA, OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT, A CANCER RISK-SPECIFIC DOSE ESTIMATE FOR 2,3,7,8-TCDD, EXTERNAL REVIEW DRAFT (1988).

[344] *Id.*

[345] Agency Information Collection Activities Under OMB Review, 57 Fed. Reg. 37,159 (1992).

tively referred to as dioxin.[345] EPA undertook this task in response to emerging scientific knowledge of the biological, human health, and environmental effects of dioxin where significant advances have been made in the scientific understanding of the following: the mechanisms of dioxin toxicity; the carcinogenic and other adverse health effects of dioxin in humans; the pathways of human exposure; and the toxic effects of dioxin to the environment.[346] EPA made the reassessment of dioxin a public effort, convening two public hearings (November 15, 1991 and April 28, 1992) to inform the public and to receive the public's comments and reviews of the proposed plans for the reassessment and to receive scientifically relevant information.

The reassessment of dioxin has consisted of five major categories of activities: (1) development of a biologically based dose-response model for dioxin; (2) update and revision of the health assessment document for dioxin; (3) laboratory research in support of the dose-response model; (4) update and revision of the dioxin exposure assessment document; and (5) research to characterize ecological risks in aquatic ecosystems. Activities (1) through (4) have been undertaken and are the basis of the draft EPA documents discussed below. The fifth activity is in progress, but the results will not be available for review until 1994.[347]

On August 18, 1992, EPA published a notice in the Federal Register concerning upcoming activities regarding EPA's reassessment of dioxin.[348] These activities related to EPA's release of draft[349] documents

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[346] *Id.* at 37,159–160.

[347] *Id.* at 37,160. For this activity, EPA is directing the efforts and conducting studies related to characterizing ecological risks in aquatic ecosystems from exposure to dioxin, including the study of organisms in aquatic food webs to identify the effects of dioxin exposure that impact populations. The data generated from this research will ultimately be used to support the development of aquatic life criteria which will be used to aid in the implementation of the Clean Water Act. *Id.*

[348] *See* 57 Fed. Reg. 37,158–59 (1992).

[349] We wish to emphasize that EPA has made the draft documents widely available to allow the public full participation in the evaluation of the issues surrounding dioxin. However, the Agency clearly underscored the "draft" status of the documents, as indicated by the "Notice" printed on all documents which states:

> Notice. This document is a preliminary draft. It has not been formally released by EPA and should not at this stage be construed to represent Agency Policy. It is being circulated for comment on its technical accuracy and policy implications.

In addition, each document contains the notation: "Draft—Do Not Quote or Cite." *See, e.g.*, U.S. EPA, EXPOSURE ASSESSMENT GROUP, OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT, ESTIMATING EXPOSURE TO DIOXIN-LIKE COMPOUNDS—REVIEW DRAFT (1992) [hereinafter EPA DRAFT EXPOSURE DOCUMENT].

[350] *Id.* The Exposure Assessment Group (EAG) developed this draft document to present procedures for conducting site-specific exposure assessments to dioxin-like compounds. This

on exposure assessment procedures[350] and health assessment issues related to EPA's reassessment of dioxin.[351] The draft documents released by EPA contain extensive technical information. A complete review and analysis of this information is beyond the scope of this article. However, an understanding of the basic protocols EPA followed and the limitations of the research is useful. Therefore, the Appendix of this article provides relevant excerpts from EPA's draft assessment material.

### *H. Welfare Effects*

In addition to health risks, welfare risks are created by acid gases, particularly hydrogen chloride (HCl), that are emitted in significant quantities. At or above ambient annual average levels of 3 ug/m$^3$, HCl corrodes ferrous metals. The majority of existing MSW incinerators exceed this level. EPA's data was unclear on whether new or more stringently regulated units would produce an HCl problem. The problem with evaluating incinerators is partly that their technology has been the result of weak regulatory requirements. Particulate matter emitted from new municipal incinerators has been regulated under CAA section 111(b) since 1974 at 0.08 grains per dscf. Since 1986 it has been regulated by the more stringent large industrial boiler standard of 0.1 pounds per million BTU for incinerators of over approximately 200 tons per day.[352]

Although dioxin and other incinerator emissions have been studied since 1984, little effective federal regulation had occurred before the 1991 regulations.[353] Because incinerator requirements were largely limited to state requirements, existing facilities present potential risks that do not represent present technology. If electric power producers were judged on the basis of their emissions in the 1950s, we would probably desire to refrain from electricity generation. The

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document, which serves as a final version of EPA's 1988 draft document entitled ESTIMATING EXPOSURE TO 2,3,7,8-TCDD, expands the scope of studied compounds to include all compounds that exhibit dioxin-like toxicity. The document covers numerous types of sites, including incinerators, landfills, and other areas characterized by contaminated soils. *Id.* at xiii. Of particular interest for purposes of this article is Ch. 6, *Municipal Solid Waste Incineration.*

[351] The second draft document released by EPA, entitled HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS (1992) is comprised of the following chapters: Ch. 1. *Disposition and Pharmacokinetics*; Ch. 2. *Mechanisms of Toxic Actions*; Ch. 3. *Acute, Subchronic, and Chronic Toxicity*; Ch. 4. *Immunotoxic Effects*; Ch. 5. *Reproductive and Developmental Toxicity*; Ch. 6. *Carcinogenicity of TCDD in Animals*; Ch. 7. *Epidemiology and Human Data*; and Ch. 8. *Dose-Response Relationships.*

[352] 52 Fed. Reg. 25,400, *supra* note 54.

[353] *See id.*

new regulation requires a ninety-five percent reduction in HCl emissions or a twenty-five ppmv emission limit.[354]

HCl is not required to be continuously monitored. It is only required to be measured once a year with a stack gas test.[355] Performance tests must be conducted in accordance with Method 26 which was also promulgated in the Federal Register on February 11, 1991.[356] Most acid gas discussion in the material included as part of the regulatory process focused on sulfur dioxide, not HCl. EPA merely concluded that the ninety-five percent HCl control is achievable.[357]

## IV. Analysis

Land disposal represents a waste of resources unless the cost of this option, including environmental costs, makes it an appropriate choice. Recycling allows waste to be used as a resource. Incineration at least allows wastes to be used for their energy value. The Bush Administration proposed a seven-fold increase in MSW incineration as part of the National Energy Strategy (NES). The NES noted that our 160 waste-to-energy plants produce useable energy that is equivalent to burning 150,000 barrels of oil each day.[358] Incineration should not be stopped because of unrealistic worst-case scenarios. Nor should it be encouraged if an option higher in the hierarchy of MSW management options is economically available.

Significant advances have occurred in recent years in the technology of air pollution controls applicable to MSW incinerators.[359] If state-of-the-art dry scrubbing systems followed by fabric filters are used, particulate emissions should be minimal. Acid gas scrubbers to control HCl and $SO_2$ will also remove organic and heavy metal pollutants.[360] Careful control of the incinerator's inlet temperature to the particulate control device limits downstream CDD/CDF formation.[361] This does not mean that incinerators are safe; rather the risk may be at or below the risks associated with other MSW management op-

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[354] 56 Fed. Reg. 5491, *supra* note 129.

[355] *Id.*

[356] *Id.* at 5525.

[357] *Id.* at 5500.

[358] *Energy Strategy Promises Major Increase in Solid Waste Incineration*, Inside EPA, Mar. 1, 1991, at 10. Note: the NSWMA says there are 136 waste-to-energy plants. *See supra* note 80.

[359] *See* 52 Fed. Reg. 25,399, *supra* note 54.

[360] Theodore G. Brna, *Toxic Metal Emissions From MWCs and Their Control*, 41 J. Air & Waste Mgmt. Ass'n, 145 (1991).

[361] Theodore G. Brna & James D. Kilgroe, *The Impact of Particulate Emission Control on the Control of Other MSW Air Emissions*, 40 J. Air & Waste Mgmt. Ass'n 1324, 1325 (1990).

tions. Even recycling is not risk-free. Incineration should then be compared to other alternatives, such as recycling, as has been done by the Environmental Defense Fund for New York City,[362] rather than using appeals to the public's fear of chemicals as the basis for decision-making.

MSW incineration is a rational option for managing solid waste. Its major weakness is the potential health problems from emissions, with emissions of dioxins/furans (CDD/CDF) being the most significant potential health risk. A second weakness is the yet unproven ability of our regulators to effectively control emissions over the life of the facility.

A definitive position on dioxins' risk will not be released by EPA for several years. Clearly more information is needed that examines dioxin exposure scenarios at levels relevant to the MSW incineration technology. EPA expects to begin drawing up a generic risk management scheme for dioxins during the summer of 1993, and several years after that, new scientific information will be used to create new regulations.[363] The Agency for Toxic Substances & Disease Registry (ATSDR), with EPA assistance, is also beginning a three-year study of the health effects of a municipal waste incinerator in North Carolina.[364] Because dioxin effects are so controversial, studies may go on indefinitely.

But the presently available risk estimates discussed above, if accurate, show an acceptable risk. Even so, it is understandable that citizens might oppose incinerators—especially existing facilities. The risk is acceptable, only because it is no greater than risks of life commonly accepted by the public. The 1991 incineration regulations adopted a thirty nanogram per dscm limit at seven percent oxygen ($O_2$) (twelve grains per billion dscf) for dioxin/furan emissions. This was the high end of the five to thirty ng/dscm limit proposed for MSW incinerators above 250 tons per day capacity.[365] What is the public health risk of this emission limit? EPA does not specifically address this issue in the regulations. The guidelines applicable to the states for existing facilities impose a much more lenient sixty and 125 ng/dscm standard on very large and large MWC plants, respec-

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[362] *See* ENVIRONMENTAL DEFENSE FUND, TO BURN OR NOT TO BURN: THE ECONOMIC ADVANTAGES OF RECYCLING OVER GARBAGE INCINERATION FOR NEW YORK CITY (1985).

[363] *'Generic' Dioxin Risk Management Document Planned For Summer 1993, EPA Official Says*, Env't Rep. (BNA) No. 22, at 1468 (Sept. 25, 1992).

[364] *New Study to Assess Health Effects of Legal Incinerator Emissions*, INSIDE EPA, Sept. 4, 1992, at 13.

[365] 56 Fed. Reg. 5491, *supra* note 129.

tively.[366] It is significant that EPA's emission limits for total dioxins/furans are not derived using health risk data, but are based on emission levels achievable by specific types of control technologies.[367]

There are seventy-five possible dioxins (also known as dibenzo-p-dioxins) and 135 chlorodibenzofuran compounds. The most common is a colorless, odorless solid known as 2,3,7,8-TCDD. This substance does not occur naturally nor is it manufactured except for small quantities used as reference standards. It is produced during incineration of hazardous and municipal waste, but it is also a contaminant in some herbicides and in the germicide hexachlorophene. It is also produced by pulp and paper manufacturing plants and from some chlorinated wastes.[368]

The only disease known to be caused by dioxin is chloracne, a severe skin lesion that is disfiguring. There is evidence that suggests it may cause liver damage and perhaps digestive disorders. It has been demonstrated to be toxic to the immune system in animals, but this toxicity has not been demonstrated in humans. In some animal species, especially monkeys, it has adverse reproductive effects and teratogenic effects. It is considered a probable carcinogen in humans.[369] There is no generally effective medical test to determine exposure to dioxin nor is there enough information to know the exposure risk from inhalation. The limited information on dioxin risks derive primarily from ingestion studies. EPA estimates the risk at 1,560 additional cases of cancer per 10,000 people exposed for a lifetime to one nanogram of 2,3,7,8-TCDD per kilogram of bodyweight each day. But based on the paucity of data, this is a mere guess of the upper limit of risk.[370]

There have been no reports of deaths in humans as a result of oral exposure to dioxin.[371] There are no studies on the inhalation toxicity of dioxin. Veterans of the Vietnam conflict have worked for years to prove that dioxin contaminated herbicide was responsible for health problems they were experiencing, but they have had great difficulty in trying to show harm.[372] Herbicide spraying would presumably re-

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[366] *Id.* at 5516.

[367] *Id.* at 5504. The regulation actually controls 31 of the 210 chemical compounds that comprise dioxins/furans. *Id.*

[368] AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, TOXICOLOGICAL PROFILE FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN 1 (1989).

[369] *Id.* at 3.

[370] *Id.* at 4.

[371] *Id.* at 11.

[372] Paul Sherman, *Agent Orange and the Problem of the Indeterminate Plaintiff*, 52 BROOK. L. REV. 369, 373, 383 (1986); Shina A. Scheindlin, *Discovering the Discoverable: A Bird's Eye*

sult in much higher exposure levels than would be expected from incinerators, especially if the 1991 MWC regulations are enforced. Again, the dioxin issue needs further research examining responses to dioxin levels relevant to the MSW incineration option. Indeed, some researchers have suggested that dioxin exposure can be greater from drinking milk than from direct exposure to inhalation sources.[373]

EPA has produced data showing a risk from incinerators that should be of concern. The public and certain environmental groups use such estimates in their efforts to oppose incineration. That a suspected but unproven carcinogen in quantities emitted from the oldest, highest polluting incinerators is the basis for the highest risk estimates is an unpublicized fact. Moreover, nonheat recovery mass burn facilities have the highest cancer risk for existing MSW incineration;[374] however, these are not the types of facilities being proposed. The baseline assumption assumed the use of only ESPs to control particulate matter[375] despite the fact that the new guidelines for large existing plants require good combustion practices[376] and a spray dryer followed by an ESP.[377] New sources have even more stringent requirements. As long as considerable controversy exists as to the potential ability of dioxin and related compounds to harm humans, the public is unlikely to embrace exposure to these substances. Nevertheless, we cannot live in a risk free society. A $10^{-6}$ risk, which seems easily achievable for MSW incinerator operation, would

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*View of Discovery in a Complex Multidistrict Class Action Litigation*, 52 BROOK. L. REV. 397, 422 (1986); Robert H. Sand, *How Much Is Enough? Observations in Light of the Agent Orange Settlement*, 9 HARV. ENVTL. L. REV. 283, 293 (1985); Charles Nesson, *Agent Orange Meets the Blue Bus: Factfinding at the Frontier of Knowledge*, 66 B.U. L. REV. 521, 523, 525 (1986).

On May 18, 1990, the Veterans Administration announced that soft-tissue sarcomas would be recognized as service-connected. This was done despite the inability to establish a causal link between exposure to the herbicide and the sarcomas; only a statistical association could be established. *Agent Orange: VA Department Recognizes Link Between Herbicide, Soft-Tissue Sarcomas*, 14 Chem. Reg. Rep. (BNA), at 394 (June 8, 1990). This resulted in non-Hodgkin's lymphoma, soft-tissue sarcoma and a skin disease—chloracne—being compensable. In July 1993, the Veterans Administration announced that Hodgkin's disease and a skin blistering condition called porphyria cutanea tarda would also be compensable. Bill McAllister, *Comprehensive Review Links Five Maladies to Agent Orange Exposure: 2 Conditions Added to List for VA Benefits*, WASH. POST, July 28, 1993, at A3.

[373] Washburn *et al.*, *supra* note 131, at 188.

[374] *Id.* at 191.

[375] 52 Fed. Reg. 25,403, *supra* note 54.

[376] Combustion practices may be more important than pollution controls, as dioxin/furans can be released from contaminants in the waste but can also be created by the combustion process itself or formed at lower temperatures downstream from the furnace. James D. Kilgroe, *Combustion Control of Trace Organics Air Pollution from Municipal Waste Combustors*, 9 ENVTL. IMPACT ASSESS. REV. 199, 201 (1989).

[377] 56 Fed. Reg. 5517, *supra* note129.

result in approximately 230 additional cases of cancer per year assuming the worst-case scenario that everyone in the United States lived a lifetime directly downwind from an MSW incinerator. Assuming they all died of cancer, this would be an increase of cancer mortality of about 0.05 percent over the 496,200 deaths due to cancer in 1989.[378] It should be noted that smoking is now considered to be responsible for up to 434,000 deaths in the United States each year.[379] The actual risks from MSW incinerators will be less than the worst-case scenario because few people actually spend their entire lives (or even a significant portion of their lives) downwind from such facilities. Many people will instead be experiencing the combined risks of living near hazardous waste incinerators, land disposal sites, industrial air polluters, low or high level radioactive waste disposal sites, or electric power plants. Even if we move away from air pollution sources, we may still face risks from nearby prisons, half-way houses and a host of other necessary public and private facilities that each present a small risk. No risk associated with waste disposal through incineration of MSW amounts to even one percent of the risk of being a murder victim.[380]

Through proper incineration practices we can probably reduce the cancer risk from MSW incinerators to even lower than $10^{-6}$.[381] The goals of good combustion practices (GCP) include: maximizing the destruction of organics in the incinerator; minimizing the release of particulate matter from the furnace; and minimizing the creation of dioxin/furan compounds downstream due to reactions in the flue gases.[382] Apparently, the new regulatory program, if enforced, would be more than adequate to protect the public health.

Monitoring and supervising incinerator operations so as to assure continued proper operation is another challenge. To encourage public confidence in MSW incineration, the monitoring provisions of the 1991 regulations should be implemented and publicized. The 1991 regulations, if implemented, would dramatically reduce the risks of incineration. It should be emphasized that much of the existing health data is based on emissions that greatly exceed what is allowed under the 1990

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[378] U.S. DEPT. OF COMMERCE, STATISTICAL ABSTRACT OF THE UNITED STATES 84 (112th ed. 1992).

[379] *See* Antonia C. Novello, *Health Hazards of Cigarette Use*, 28 TRIAL, Mar. 1992, at 46.

[380] Kemper, *Biting the Bullet*, COMMON CAUSE MAG., Winter 1992, at 16, 20 (24,020 murders in 1991).

[381] The 1991 regulations are projected to reduce air emissions from incinerators by 200,000 tons of pollutants per year by 1999. *EPA Strengthens Air Emissions Standards for Municipal Waste Incinerators*, 41 J. AIR WASTE MGMT. ASS'N 259 (1991).

[382] Brna & Kilgroe, *supra* note 361.

CAA. The monitoring provisions are also greatly strengthened.[383] Still, more could be done to encourage public acceptance.

To make MSW incineration more acceptable, the following elements should be incorporated into a permit:

1. the stacks should be tested either annually or semi-annually by an independent consultant and the report should be made publicly available;
2. to the extent possible, continuous emissions monitoring should be used and the data should be readily available to the public;
3. automatic shut-down equipment that would terminate operation of the facility if operational parameters are exceeded should be required; and,
4. those maintenance and operation records that are required to be kept and that are public information should be easily accessible to the public.[384]

If incineration is ever to be accepted by the public, the monitoring and enforcement process needs to be improved substantially. At the Baird-McGuire site in Massachusetts, EPA Region I officials are considering installing a monitor with a twenty-four-hour readout at the city hall. This would increase community oversight of the incinerator's operation.[385] If this is what is required to create public confidence in the environmental protection effort, it should be done.

## V. CONCLUSION

Environmentalists oppose MSW incinerators for several reasons. Some believe there are serious health hazards associated with MSW incinerators[386] despite the data that projects a risk far below that posed by death inflicted by other factors such as drunk drivers[387] or homicide.[388] Some oppose incinerators because they do not believe

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[383] *See supra* notes 304–309 and accompanying text.

[384] Prall Culviner, *Denmark Chooses Combustion*, WASTE AGE, Apr. 1990, at 179.

[385] *Public Opposition to Incinerating Waste Could Seriously Impede Cleanups, Officials Say*, 23 Env't Rep. (BNA) No. 33, at 2028 (Dec. 11, 1992).

[386] *Greenpeace Report Targets Incinerators as Major Polluters, Urges Ban*, CLEAN AIR REPORT, June 6, 1991, at 9. Greenpeace disputes the scientific evidence claiming that much of the study of dioxin has been conducted by the Dow and Monsanto Corporations and by the German chemical company BASF. They claim the studies were manipulated and are scientifically invalid. Joe Thornton & John Hanrahan, *The Dioxin Deception*, GREENPEACE MAG., May/June, 1991, at 16–17.

[387] Drunk driving deaths in 1988: licensed drivers: 164,197,000; fatal accidents involving drinking drivers: 20,208; chance of driver being involved in fatal accident without drunk driver: 0.0001231. U.S. DEPT. OF COMMERCE, STATISTICAL ABSTRACTS OF THE UNITED STATES 608 (110th ed. 1990).

[388] Murder per 10,000 population in 1988: average for 7,434 cities: 10.5. The rate for N.Y. is 25.8, and for D.C. it is 59.5. *Id.* at 172.

they will be appropriately regulated. Others oppose incineration because they believe it will hamper recycling efforts.[389] A coalition of twelve environmental organizations, including the Environmental Defense Fund (EDF), the Natural Resources Defense Council (NRDC), and the Sierra Club, have called for a complete moratorium on the construction of new MSW incinerators until the year 2000 to encourage waste reduction and recycling.[390] Moreover, some organizations believe that a gridlock on solutions to solid waste issues will compel a change in life-styles in the direction of greater harmony with our ecosystem.[391] Industry, however, sees the high cost of incineration as a significant incentive for waste minimization. Forcing people to pay the true cost of disposal through proper incineration gets rid of existing waste and encourages waste reduction efforts.[392] It is critical to ensure that the cost of each manufactured object includes the cost of environmentally protective disposal.[393] In such circumstances, manufacturers would have an incentive to devise more environmentally appropriate products, and consumers would have a voice in the cost-effective solutions.[394]

However, much of the public opposition to incineration is irrational or motivated by considerations having little to do with environmental or public health protection. The intensity of opposition is fueled by environmental groups who, rather than finding overriding faults with MSW incineration, oppose the siting of incinerators in order to bring about dramatic changes in the way society consumes materials and products. Some of the NIMBY opposition to incineration is an attempt to shift equal or greater risks to another jurisdiction by requiring a non-incineration option that will be located in a different jurisdiction. We need to confront the NIMBY problem which vastly impacts waste-disposal costs. These opponents will never be satisfied, but perhaps a majority of the public can be convinced to evaluate the

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[389] *Trash Incinerators Would Hamper Recycling, Should Be Limited Under RCRA, Senate Panel Told*, 22 Env't Rep. (BNA) No. 21, at 1342 (Sept. 20, 1991).

[390] *RCRA Reauthorization—Environmentalists Urge Moratorium on Incinerators*, ENVTL. POL'Y ALERT, June 12, 1991, at 11; *Environmentalists Push Mandated MSW Recycling, Raw Material Fee in RCRA*, INSIDE EPA, June 14, 1991, at 14.

[391] Greenpeace is challenging incineration in North Carolina, Ohio, California, Illinois, Michigan, Missouri, and Florida. *Judge Orders Shutdown at Dioxin Burn Site; Defendants Appeal Decision to Eighth Circuit*, 7 Toxics L. Rep. (BNA) No. 38, *supra* note 163, at 1119.

[392] *Industry, Congressional Staff Reject Ban, Say Cost Will Limit Burners*, CLEAN AIR REP., June 6, 1991, at 9.

[393] Daniel E. Koshland, Jr., *Priority One: Rescue the Environment*, SCIENCE, Feb. 16, 1990, at 777. Like in mining, the manufacturing of an object should be subject to laws relating to incineration (or recycling) which would be supported by the cost of the object. *Id.*

[394] *Id.*

MSW management options consistently.[395] While the aim—forcing a rethinking of consumer choices—is laudable, the call for a ban on the siting of MSW incinerators is not. There are other ways to ensure that the costs of products include their costs of disposal and concomitantly to ensure that MSW management practices are safe for humans and the environment. The impassioned rhetoric that surrounds the option of recycling has been described as "an environmental moralism that skirts the practical problems of how to sort household trash and find markets for recycled materials."[396] While recycling holds much promise in easing pressures on landfills and conserving valuable resources, it alone cannot solve the MSW problem. In addition to source reduction, MSW incineration needs to be part of the solution. Incineration reduces the "garbage mountain" and can provide a useful byproduct, i.e., electricity.[397] Communities must begin to recognize that incineration can be an environmentally benign and efficient way to deal with the MSW problem.[398] Thus, the options should not be considered wholly independent. Rather, they should be seen as complementary so that MSW management in the United States is environmentally and economically optimal.

Nevertheless, incineration creates a level of opposition that is not typically found in the process of selecting other options such as landfills. For example, a hazardous waste incinerator in East Liverpool, Ohio has been the subject of community opposition for twelve years. Citizens have sued and gone on hunger strikes. They have also been arrested at the site, at the Ohio EPA headquarters, and at the EPA's offices in Washington, D.C. In the Autumn of 1992, more than a hundred demonstrators were arrested at the site protesting a planned shakedown burn.[399] Whether dispassionate analysis of the

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[395] However, the public may simply reject the incinerator option. A regulation went into effect on Sept. 11, 1992 in Ontario, Canada that will ban future MSW incinerators. The Ministry was concerned with toxic emissions, potential hazardous residuals, the high cost of incineration, and the loss of the opportunity to recycle materials. Orchard, *Report From Canada*, 42 J. AIR WASTE MGMT. ASS'N 1548 (1992).

[396] Edgar Berkey, *Confronting the Garbage Glut*, HARTFORD COURANT, July 23, 1990, at B11.

[397] *Id.* For example, five waste-to-energy facilities are operating or are under construction in Connecticut. Together, they can burn 67 percent of the state's MSW and the process reduces the volume of garbage by 90 percent. *Id.*

[398] *Id.*

[399] *Gore Says Clinton Administration Will Back Trial Burn of WTI Incinerator*, 23 Env't Rep. (BNA) No. 33, at 2029 (Dec. 11, 1992). *See also* Keith Schneider, *The Environmental Fix With a Legion of Doubters*, N.Y. TIMES, Dec. 20, 1992, § 4, at 5; Tom Kenworthy, *Incinerator in Ohio Poses Balancing Test for Clinton-Gore Policies*, WASH. POST, Jan. 2, 1993, at A4. A full page advertisement by the proponents of the incinerator defending its siting appeared in the WASHINGTON POST, Dec. 15, 1992, at A20. It should be emphasized that this intense opposition is fueled by the incinerator's close location to a school and to residential property.

solid waste management options can overcome this level of citizen passion is unknown. In any event, environmental professionals have a duty to continue their efforts to understand the actual risks of each solid waste management option and to develop and implement the processes and technology necessary to minimize the risks. The key is to ensure that we utilize an integrated program of source reduction, recycling, incineration, and landfills using state-of-the-art technology. We will not solve the MSW problem unless all options are pursued together. Therefore, at this time, MSW incineration appears to be a viable waste management option with the advantage of permanently disposing of much of the waste. Its use helps to solve the pernicious problem of appropriate MSW management and disposal. It may not be the perfect solution, but what is?

# APPENDIX

The following provides relevant excerpts from two EPA draft documents concerning the environmental and health effects surrounding the dioxin issue.[400]

I. ESTIMATING EXPOSURE TO DIOXIN-LIKE COMPOUNDS.

The primary purpose of this document is to present procedures for conducting site-specific exposure assessments to dioxin-like compounds. Information is provided on the levels of these compounds found in various media, identification of the possible sources, and estimates of the resulting exposure levels. The types of sites covered in this document include MSW incinerators, landfills, and other areas involving contaminated soils. The procedures outlined in the document identify possible exposure pathways associated with these sites, present fate models to estimate media concentrations at the point(s) of exposure, and identify ways to estimate contact rates and resultant exposure levels.[401]

This document provides methodologies and background information for conducting site-specific exposure assessments to dioxin-like compounds. While most of the details of this document are beyond the scope of this article, it is worthwhile to briefly summarize the chapters directly pertinent to this discussion. Specifically, Chapters 3, 6, 7, 9, and 11 are discussed.[402]

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[400] We wish to emphasize that EPA has made the draft documents widely available to allow the public full participation in the evaluation of the issues surrounding dioxin. However, the Agency clearly underscored the "draft" status of the documents, as indicated by the "Notice" printed on all documents which states:

> Notice. This document is a preliminary draft. It has not been formally released by EPA and should not at this stage be construed to represent Agency Policy. It is being circulated for comment on its technical accuracy and policy implications.

In addition, each document contains the notation: "Draft—Do Not Quote or Cite."

[401] EPA DRAFT EXPOSURE DOCUMENT, *supra* note 349, at 1–1.

[402] The chapters not discussed here are identified as follows. Chapter 2 describes the physical and chemical properties of the dioxin-like compounds. Chapter 4 presents the overall framework for conducting exposure assessments and discusses the use of Toxicity Equivalency Factors (TEFs). Chapter 5 provides procedures for estimating concentrations of the dioxin-like compounds in exposure media resulting from soil contamination and nearby incinerators. Chapter 8 summarizes information about uptake and distribution of dioxin-like compounds in the human body and presents pharmacokinetic models to predict blood levels resulting from exposure. Chapter 10 discusses the sources and possible magnitude of uncertainty in the exposure assessment procedures.

**Chapter 3. Environmental Levels of PCDD, PCDF, and PCB Congeners.**

This chapter summarizes the levels of dioxin-like compounds found in various media. Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated biphenyls (PCBs) are found in all media (air, soil, and water), and are ubiquitous in fish and shellfish, meat, milk, and vegetation.[403] Although the manufacture of most chlorinated phenolic products, including PCBs, ceased in the late 1970s, the continued use and disposal of these compounds results in the release of PCDDs, PCDFs, and PCBs to the environment.[404] Other sources of dioxin compounds include releases from the combustion of municipal and chemical wastes, chlorination of municipal water, release of household bleaches into sewer systems, and chlorine bleaching processes in paper mills.[405] Because of these processes, PCDDs, PCDFs, and PCBs become available for human exposure via various pathways.[406]

The chapter provides the ranges of these compounds found in air,[407] soil,[408] water,[409] sediment,[410] fish and shellfish,[411] and food[412] from limited

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[403] EPA DRAFT EXPOSURE DOCUMENT, *supra* note 349, at 3–1. PCDDs and PCDFs are contaminants that are released to the environment as byproducts of the manufacture of such chlorinated compounds as polychlorinated phenols, PCBs, phenoxy herbicides, hexachlorobenzene, and chlorodiphenyl ethers. *Id.*

[404] *Id.*

[405] *Id.*

[406] *Id.*

[407] Limited ambient air measurements have been carried out in selected cities in the U.S. and Europe. There are similarities with respect to the magnitude of specific congeners of PCDDs and PCDFs, and specific dioxin-like congeners are quantified from 1/10 to 1/100 picograms per cubic meter of air sample. *Id.* at 3–20.

[408] General observations for PCDD and PCDF levels in soils based on the various reported data indicate that concentrations associated with industrial sites are the highest, with concentrations in the hundreds to thousands of parts per trillion (ppt). *Id.* at 3–5. Also, as might be expected, concentrations in urban settings are higher than those in rural areas. *Id.*

[409] General observations indicate concentrations of 2,3,7,8-TCDD in the parts per quadrillion (ppq) in surface waters. *Id.*

[410] The studies indicate that the concentration patterns in sediments of PCDDs and PCDFs are usually the result of industrial combustion processes, and they decrease with distance from the source. *Id.* at 3–12.

[411] Fish and shellfish differ in their ability to bioconcentrate PCDD and PCDF congeners. *Id.* at 3–17. For fish, the concentrations of PCDD and PCDF are dependent on exposure level, fat content, habitat, and amount of movement of the species. *Id.* Comparatively fat bottom-dwelling fish collected close to the contaminant source have the highest PCDD/PCDF levels, while leaner non-stationary fish have lower concentrations. *Id.* at 3–18.

[412] The studies examined PCDD and PCDF levels in products of animal origin (i.e., fish, meat, eggs, and dairy products). The data indicate that these compounds are found at levels ranging from the intermediate parts per quadrillion (ppq) up to the low parts per trillion (ppt) range. *Id.* at 3–18.

studies. These data provide a general indication of these compound levels in the various media throughout the world.[413]

**Chapter 6. Municipal Solid Waste Incineration.**

This chapter provides procedures to estimate the emission rates of dioxin-like compounds from MSW incinerators, including stack and fly ash emissions. The combustion of MSW releases potentially harmful pollutants to the air from incinerator stacks. Of particular concern is the potential human health and environmental effects of the emissions during the period of incinerator operation. Various theories have been proposed to explain the presence of dioxins (such as PCDDs and PCDFs) in MSW incinerator emissions.[414] These theories include the following: (1) the compounds are present as contaminants in bleached paper or other MSW constituents, and some portion of them survives the incineration process; (2) the compounds result from *de novo* synthesis from precursors, such as PCBs, chlorophenols, and chlorinated benzenes; and (3) the compounds are synthesized from materials unrelated to PCDDs or PCDFs, such as petroleum products, polynuclear aromatic hydrocarbons (PAHs), inorganic chloride ions, and plastics.[415] Researchers have postulated that PCDDs and PCDFs are created on the reactive surface of fly ash (i.e., particulate matter) downstream of the furnace zone where the temperature of combustion offgases have cooled between 200° and 400°C.[416] Based on experiments, these researchers believe that inorganic chloride ions, such as copper chloride, present in the combustion gas may act as a catalyst to promote surface reactions on particulate matter which converts aromatic compounds to chlorinated dioxins and dibenzonfurans.[417] Further, it appears that the formation of PCDDs and PCDFs on the surfaces of fly ash during MSW incineration occurs in a temperature window.[418]

One series of experiments discounts the likelihood of the first theory of dioxin emissions, namely that dioxin in the MSW accounts for dioxin emissions at the stack.[419] The air emission of PCBs from MSW

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[413] Although there are historical and geographic differences in background exposure, a worldwide Toxic Equivalent Concentration (TEq) was determined to be in a range from 20–90 picograms per day. *Id.* at 3–25.

[414] EPA DRAFT EXPOSURE DOCUMENT, *supra* note 349, at 6–5.

[415] *Id.*

[416] *Id.*

[417] *Id.*

[418] *Id.* at 6–6.

[419] In a series of tests of an RDF facility, approximately 5 milligrams of total PCDD and PCDF per metric ton of MSW were measured in the refuse prior to combustion, but neither PCDDs nor PCDFs were detected at the exit to the furnace prior to the inlet to the economizer (the heat exchanger used to extract additional heat from the hot gases). Once the heat in the

incinerators is less understood, but based on various tests, it appears that PCB contamination in the raw MSW that is fed into the incinerator may account for the emission of PCBs.[420]

For purposes of exposure analysis, EPA chose a hypothetical, but realistic, incinerator design, location and set of environmental conditions.[421] EPA then estimated the mass rate of emission of specific congeners of PCDDs, PCDFs and PCBs from the stack of the hypothetical MSW incinerator.[422] The mass of ash that is produced as a residue from the combustion of MSW on the grate within the incinerator (bottom ash), and the ash that was collected by the particulate matter control device (fly ash), were also estimated. This estimation was useful for the analysis of human exposures to dioxin-like compounds after storing, transporting, and disposing of the ash residues from the incinerator into a landfill.[423] In addition, EPA estimated deposition of the dioxin-like compounds emitted from the stack of the hypothetical MSW incinerator.[424]

Ambient air and surface deposition modeling of emissions for the hypothetical incinerator were estimated for two pollution control scenarios: (1) ESP; and (2) dry scrubber combined with fabric filter (DSFF).[425] The air dispersion modeling for both scenarios indicated that maximum ambient air and surface deposition concentration of modeled congeners was 200 meters east of the incinerator (corre-

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combustion gas was extracted for energy purposes, and the gases were further cooled to within the "window" of temperatures that promote dioxin formation on fly ash surfaces, then the total array of PCDDs and PCDFs could be detected. *Id.* at 6–9. Thus, this series of experiments in which the mass balance of PCDD/PCDF was estimated for the entire combustion process discounts the theory that dioxin originally in the MSW accounts for dioxin emissions at the stack. *Id.* at 6–8 to 6–9.

[420] *Id.* at 6–9. Unlike the mechanism of formation of PCDDs and PCDFs, empirical data do not support a theory of *de novo* synthesis of PCBs. *Id.* at 6–9 to 6–10.

[421] *Id.* at 6–9. The mass burn, heat recovery incinerator technology was selected. This technology dominates the existing and projected census of U.S. incinerators. The hypothetical incinerator was assumed to have a combined daily combustion capacity of 2,727 metric tons per day (3000 tons/day). EPA selected the stack height, diameter, exit velocity of the emissions, and temperature of the exhaust gases based on actual data from like facilities. The hypothetical facility was located in Tampa, Florida, a site characterized as a wet, humid geographical area where the MSW incineration industry is expected to grow significantly over the next 15 years. *Id.* at 6–10 to 6–11.

[422] *See id.* at 6–12 to 6–25.

[423] *See id.* The dioxin-like compounds are primarily associated with the fly ash; negligible amounts of PCDDs/PCDFs have been detected on bottom ash from the combustion grate because these chemicals are synthesized outside the furnace region. Thus, combining fly ash with bottom ash prior to disposal typically dilutes the initial contaminant concentration, especially in light of the fact that the mass ratio of bottom ash to fly ash is about 10:1. *Id.* at 6–26.

[424] *Id.* at 6–34 to 6–40.

[425] *Id.* at 6–41 to 6–48.

sponding to a westerly wind direction).[426] Further, most of the ground-level impact associated with stack emissions will occur within five kilometers from the incinerator for both control scenarios.[427]

**Chapter 7. Exposure Scenario Development.**

Chapter 7 provides procedures for identifying exposure pathways, and estimating contact rates and resulting exposure levels. Approaches for exposure scenario evaluation[428] as applied to dioxin-like compounds are presented. As discussed above, dioxin-like compounds have been found primarily in air, soil, sediment and biota (and in water to a lesser degree).[429] As noted above, the typical exposure[430] pathways were considered. Specifically, EPA estimated exposure values[431] for soil ingestion,[432] soil dermal contact,[433] vapor and dust inhalation,[434]

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[426] *Id.* Ambient air concentrations at ground level of dioxin-like congeners are expressed in units of grams per cubic meter of air ($g/m^3$). *Id.*

[427] *Id.* Surface deposition flux is expressed in units of grams per square meter per year ($g/m^2$ x yr). *Id.* at 6–46.

[428] *Id.* at 7–1. In an exposure scenario evaluation, the concentrations of chemicals in a medium or location is determined and linked with the time that individuals or populations come in contact with the chemical(s). *Id.* at 7–1.

[429] *See infra* notes 403–13 and accompanying text.

[430] Exposure is calculated as the potential dose normalized against body weight and lifetime. *Id.* at 7–3. This value is computed as the lifetime average daily dose (LADD) for all exposure pathways where:

> LADD = (exposure media concentration x contact rate x contact fraction x exposure duration)/(body weight x lifetime).

*Id.* "Lifetime" refers to the expected lifetime of the exposed individuals; EPA recommends using the U.S. average of 70 years for all pathways as a default value. *Id.* at 7–4. "Body weight" refers to the average body weight of the exposed individuals over the exposure period; EPA recommends using the U.S. average of 70 kg for all pathways involving adults, and 16 kg for children ingesting soil. *Id.* "Exposure media concentration" is the concentration of the chemical in the media of interest averaged over the time of exposure. *Id.* "Exposure duration" is the overall time period that individuals spend in situations that expose them to a contaminated media; EPA recommends a range of 9 to 30 years. *Id.* "Contact rate" is the total rate of contact with the exposure media via ingestion, dermal contact, or inhalation. "Contact fraction" is the portion of contacted material that is contaminated. *Id.* at 7–4 to 7–5. Although exposure factors are best determined on a site-specific basis, generic default values (typically a range from central to high end values) can be used when site-specific values are not available. *Id.* at 7–3.

[431] EPA's summary of exposure pathway parameters is provided in Table 7–1. *Id.* at 7–13 to 7–15.

[432] Soil ingestion commonly occurs among children during activities such as mouthing of toys, nonsanitary eating habits, inadvertent hand-to-mouth transfers, and intentional soil ingestion. To a much lesser degree, soil ingestion occurs in adults, but the data is sparse. *Id.* at 7–5. EPA estimated soil ingestion for young children (under age seven) at approximately 0.1 to 0.2 grams per day. *Id.* at 7–6.

[433] Three factors control soil dermal contact (expressed in mg/year): the contact rate per soil contact event, the surface area of contact, and the number of dermal contact events per year. EPA provided the following ranges: contact rate—0.2 to 1.0 $mg/cm^2$-event; adult surface area—5,000 to 5,800 $cm^2$; and event frequency—40 to 350 events per year. *Id.*

[434] For vapor and dust inhalation, EPA cited typical ventilation rates of 20 and 23 $m^3$/day, and used 20 $m^3$/day in the assessment. *Id.* at 7–7.

water ingestion,[435] beef and dairy product ingestion,[436] fish ingestion,[437] and ingestion of fruits and vegetables.[438]

**Chapter 9. Demonstration of Methodology.**

Chapter 9 integrates the information concerning site-specific methodologies and develops hypothetical exposure scenarios.[439] Exposure scenarios were developed which are associated with four source categories: (1) on-site soil;[440] (2) off-site soil;[441] (3) incinerator stack emissions;[442] and (4) incinerator ash disposal in a landfill.[443] Three dioxin-like compounds were demonstrated for each of the exposure scenarios.[444]

The results of this assessment of exposure scenarios included exposure media concentrations for all exposure pathways, and exposure estimates which are Lifetime Average Daily Doses (LADDs) for all pathways and example compounds.[445] EPA cautions, however, that "these observations are not generalizable comments. Different results would arise from different source strength characteristics, proximity considerations, model parameter values, different models altogether, and so on."[446]

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[435] The water ingestion rate of 2 liters/day is traditionally used for exposure through drinking water. EPA considered this a high end value, however, and used 1.4 liters/day as representative of average adult drinking water consumption for purposes of this assessment. *Id.* at 7–8.

[436] EPA used an average beef fat consumption rate of 22 grams/day and an average milk fat consumption rate of 10.5 grams/day. *Id.* at 7–9. It should be noted that if contaminated beef and dairy products from one source are marketed along with uncontaminated products from another source, only a small percent of the beef and dairy consumed by an individual may be contaminated. *Id.* This "market dilution" can introduce much uncertainty in human exposure assessments.

[437] EPA used judgment concerning fish consumption rate data and used rates of 1.2 grams/day for central estimates, and 4.1 grams/day for high end estimates. *Id.* at 7–10 to 7–11.

[438] EPA used 200 grams/day and 140 grams/day as average amounts of fruit and vegetable consumption, respectively. *Id.* at 7–11. Note that EPA distinguished between above-ground unprotected and below-ground unprotected categories for each category of exposure. *Id.* at 9–1.

[439] *Id.* at 9–1.

[440] Here, the source of contamination is soil and both the source and exposure site are on the same tract of land. *Id.*

[441] The source of contamination is soil and this source is located distant from and upgradient (upwind) of the site of exposure. *Id.*

[442] In this source category, exposed individuals reside downwind of the incinerator and are exposed to resulting air-borne vapor phase contaminants originating at the incinerator, and soil on their property is impacted by the deposition of contaminated particulates. *Id.*

[443] In this category, contaminated ash is spread onto the surface of an active landfill, and exposed individuals reside upgradient (upwind) of the landfill. *Id.* at 9–1 to 9–2. [This presumably is an error and should read "downgradient."]

[444] These were: 2,3,7,8-TCDD; 2,3,4,7,8-PCDF; and 2,3,3',4,4',5,5'-HPCB. *Id.* at 9–2.

[445] *Id.* at 9–2, 9–16.

[446] *Id.* Exposure media concentrations estimated for all scenarios and pathways are provided in Table 9–2. *Id.* at 9–17 to 9–19. The LADD estimates (in mg/kg-day) for all scenarios and exposure pathways are provided in Table 9–3. *Id.* at 9–20 to 9–22.

Briefly, the modeled results exhibited the following trends. Concentrations of the example contaminants in soil for soil ingestion and dermal contact pathways varied under the scenarios and with distance from the hypothetical incinerator, but were in the ug/kg (=ppt) range.[447] "Concentrations of contaminants in the vapor phase range[d] from $10^{-11}$ to $10^{-8}$ ug/$m^3$."[448] Particulate-phase air-borne contaminant concentrations "were 1 to 3 orders of magnitude lower than vapor-phase concentrations for the same scenario."[449] "Concentrations of the example contaminants in drinking water were $10^{-14}$ to $10^{-9}$ mg/L (=ppm)."[450] "Concentrations in fish ranged from $10^{-9}$ to $10^{-4}$ mg/kg."[451] Concentrations in fruit and vegetables "ranged from $10^{-11}$ to $10^{-7}$ mg/kg (=ppm)."[452] Concentrations in beef and milk were comparable to fish and ranged from $10^{-9}$ to $10^{-3}$ mg/kg.[453]

Finally, there were reportable trends for the analyses of Lifetime Average Daily Dose estimates. Overall, the LADD estimates ranged from $10^{-17}$ mg/kg-day to $10^{-8}$ mg/kg-day.[454] The highest exposure estimates were associated with the ash landfill and the off-site soil contamination scenarios, which had the highest exposure media concentrations for all exposure media.[455] Exposures associated with stack emissions and on-site soil contamination with low soil concentration were similar, with a range of $10^{-17}$ to $10^{-10}$ mg/kg-day.[456] Again, EPA noted these estimates cannot be safely used outside the parameters of these modeling exercises because of the complex interplay of fate and transport modeling, food chain modeling, assumptions about the physical environment, and about exposure behavior.[457] The uncertainty in these estimates is described fully in Chapter 10 and is also summarized below.

**Chapter 11. Conclusions and Recommendations.**

Finally, Chapter 11 presents the conclusions concerning how humans are exposed to dioxin-like compounds and offers recommendations for future research to help resolve the uncertainties that have plagued dioxin assessments.[458] These are briefly summarized below.

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[447] *Id.* at 9–16, 9–22. The range of concentrations for soil exposure is not easily summarized.
[448] *Id.* at 9–23.
[449] *Id.* at 9–24.
[450] *Id.* at 9–25.
[451] *Id.*
[452] *Id.* at 9–26.
[453] *Id.*
[454] *Id.* at 9–27.
[455] *Id.*
[456] *Id.*
[457] *Id.* at 9–35.
[458] *Id.* at 11–1.

The primary findings and conclusions of the assessment indicate that dioxin-like compounds are commonly found in soils, sediments and biota throughout the world.[459] Concentrations in non-industrial rural areas are typically lower than in urban or industrial areas.[460] Overall, the assessment suggests a background exposure level in the range of 20–90 pg of TEq/day for total dioxin-like compounds using data for world-wide sources.[461]

In addition, the draft document provides estimations of individual exposures to four categories of contamination sources:[462] (1) on-site soils—i.e., the soil contamination and exposure occur at the same site;[463] (2) off-site soils—i.e., the contaminated soil is spatially separated from the site of exposure;[464] (3) incinerator stack emissions—i.e., individuals near incinerators are directly exposed via inhalation of impacted air and indirectly exposed as a result of the deposition of contaminated emissions onto soils and vegetation;[465] and (4) ash landfill—i.e., similar to the off-site soil category except that the source of exposure is incinerator ash.[466] The report indicates that exposures estimated for individuals living near areas of relatively high soil concentrations (i.e., the off-site soil and ash landfill categories) were two to three orders of magnitude higher as compared to the on-site and stack emission exposure estimates.[467] The highly generalized conclu-

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[459] *Id.*

[460] *Id.*

[461] *Id.* The estimated background exposure to all compounds was estimated by multiplying the average media levels by typical contact rates. *Id.* Of course, this model assumes all pathways are equally additive. In addition, this estimate is highly qualified because of the relatively few world-wide studies and the numerous assumptions made concerning background levels and other parameters. *Id.* Typical exposure levels to 2,3,7,8-TCDD using pharmacokinetic models were estimated to be between 20–40 pg/day. This estimate is consistent with the analysis for exposure to total dioxin-like compounds. *Id.* at 11–1 to 11–2.

[462] *Id.* at 11–2.

[463] *Id.* The on-site source category was demonstrated assuming soil levels of 1 ng/kg (=ppt) which was characterized as typical of soil levels of background or rural areas. *Id.* at 11–3 to 11–4.

[464] *Id.* at 11–2. The off-site soil source category was demonstrated assuming 1 ug/kg (=ppb) concentrations in a contaminated area located 150 meters from a farm. *Id.* at 11–4. This soil concentration was considered as typical of soils of known industrial contamination by dioxin-like compounds. *Id.*

[465] *Id.* at 11–2. The stack emission source category was demonstrated using emission rates specific to a fabric filter combined with semi-dry alkaline scrubbers emission control technology. *Id.* at 11–4. This scenario was considered a high level of emission control in use for a small number of currently operating incinerators. *Id.* However, it would be more commonplace for new incinerators. *Id.*

[466] *Id.* at 11–2. The ash landfill soil concentrations were developed given estimated ash concentrations based on use of the same emission control technology as for the stack emission source category. *Id.* at 11–4. Resulting landfill concentrations were in the low ppb range, and exposed individuals resided 150 meters from the landfill. *Id.*

[467] *Id.*

sions indicate that the highest human exposures estimated were associated with farm (beef and dairy) products.[468] The prevalence of food chain exposures is explained by the tendency of dioxin-like compounds to bioaccumulate in food products of high fat content and the related ingestion rates of these food products.[469] Other exposures occur through dermal contact with soil and soil ingestion. To a lesser degree, exposures occur through inhalation, fruit and vegetable ingestion, and water ingestion.[470]

Finally, the draft document recommended further research in several critical areas: (1) the lack of congener-specific data is cited as a major source of uncertainty; (2) the use of pharmacokinetics in estimating exposure levels; (3) estimating fish tissue concentrations; (4) the components of the model to estimate dairy (beef and milk) concentrations; (5) the evaluation of additional exposure pathways (e.g., ingestion of other farm products such as chickens, eggs, and pork); (6) comprehensive inventory of key sources of dioxin-like compound contamination; and (7) reduction in uncertainty in several model parameters to increase the reliability of estimates.[471] It is clear that, although our understanding of the dioxin issue is expanding, there continues to be a critical lack of certainty on many fronts.

II. HEALTH ASSESSMENT FOR TCDD AND RELATED COMPOUNDS.

The other draft document[472] released by EPA in 1992 is a comprehensive technical document that assesses the state of scientific knowledge concerning the effects of TCDD and related compounds on human health. Although the findings presented in this document are, for the most part, extremely technical and beyond the scope of this article, any evaluation of the health effects of dioxin must address the issues raised in this document. Therefore, a brief summary of the key findings reported in the eight draft Health Assessment chapters of this document is instructive. Overall, while this document represents the most recent findings, it reaches no final conclusion and it indicates the continuing uncertainty surrounding the dioxin issue.

**Chapter 1. Disposition and Pharmacokinetics.**

The disposition and pharmacokinetics of 2,3,7,8-TCDD and related compounds were investigated in several species and under various

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[468] *Id.* Fish ingestion was of primary concern when not overshadowed by ingestion of farm products. *Id.*

[469] *Id.* at 11–2 to 11–3.

[470] *Id.* at 11–3.

[471] *Id.* at 11–7.

[472] *See supra* note 351. This draft document is comprised of eight chapters concerning the health assessment. *Id.*

exposure conditions. The major focus of the study concerned the absorption and bioavailability following exposure through diet (i.e., gastrointestinal absorption) or skin contact (i.e., dermal absorption) because they represent potential routes for human exposure to this class of persistent environmental contaminants.

The first major source of human exposure to 2,3,7,8-TCDD and related compounds is the diet.[473] Oral exposure of humans to 2,3,7,8-TCDD and related compounds was reported as a complex mixture of these contaminants in food, soil, dust, water or other mixtures that would be expected to alter absorption.[474] Gastrointestinal absorption studies on animals and humans showed significant variability, and often depended on a number of factors beyond the scope of this article.

The second major source of human exposure is dermal absorption. Dermal exposure of humans to 2,3,7,8-TCDD and related compounds typically occurs as a complex mixture of these contaminants in soil, oils or other mixtures which would be expected to alter absorption.[475] Like gastrointestinal absorption, rates of dermal adsorption varied considerably among species, including humans, and this subject is beyond the scope of this article.

Following absorption, TCDD and related compounds are distributed in blood and lymph by binding to components in blood to enable them to diffuse through blood vessels and tissue membranes.[476] Once absorbed into blood, TCDD and related compounds readily distribute to all organs,[477] although within several hours the liver, adipose tissue, and skin become the primary sites of disposition.[478]

Distribution of TCDD and related compounds is also time dependent. In general, these compounds are cleared rapidly from the blood and distributed to liver, muscle, skin, adipose tissue and other tissues within the first hour(s) after exposure.[479] This is typically followed by redistribution to the liver and adipose tissue, which exhibit increasing tissue concentrations over several days after exposure.[480] Elimination from tissues thereafter occurs at rates that are dependent on other

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[473] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 1-1 (1992).

[474] *Id.* at 1-6.

[475] *Id.* at 1-11.

[476] *Id.* at 1-14.

[477] *Id.* at 1-16.

[478] *Id.* at 1-17. These results are based on laboratory animals; similar results were determined for humans. *Id.* at 1-20.

[479] *Id.* at 1-22. Such disposition will, of course, vary, depending on tissue, species, and time after a given exposure. *Id.*

[480] *Id.*

factors and are congener (related dioxin-like compounds), tissue, and species specific.[481] Thus, the ratio of the concentrations of TCDD and related compounds in different tissues may not remain constant over an extended time period following a single exposure.

Although early studies were unable to detect the metabolism and excretion of TCDD, there is now evidence that this can occur.[482] Recent data regarding fecal samples from humans suggest that humans can metabolize 2,3,7,8-TCDD,[483] and data is available demonstrating that other organisms, such as rats, mice, guinea pigs, and hamsters can metabolize TCDD as well as other congeners.[484] The metabolism of TCDD and related compounds is required for urinary and biliary elimination and, therefore, plays a significant role in regulating the rate of excretion of these compounds. Further, metabolism is currently considered a detoxification process,[485] whereby the metabolites formed are significantly less toxic than the parent compound(s). Studies of excretion in humans (as well as animals) indicate that 2,3,7,8-TCDD is exceedingly persistent, with half-lives of TCDD or other congeners ranging from 0.8 to 10 years.[486]

The elimination of TCDD through mother's milk can result in high exposure levels in infants. High levels of 2,3,7,8-TCDD have been detected in the milk of mothers exposed to high levels of that compound in the environment.[487] In addition, the sex of the animal, pregnancy, and/or route of exposure could have a significant impact on the pharmacokinetics of TCDD and related compounds.[488] Further, the results of various studies concerning aging indicate that TCDD is absorbed to a greater degree through the skin of very young animals and that a significant decrease in potential for systemic exposure may occur during maturation and again during aging.[489]

Finally, physiologically-based pharmacokinetic (PB-PK) models[490]

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[481] *Id.*

[482] *Id.* at 1–42.

[483] *Id.* at 1–43.

[484] *Id.*

[485] *Id.* at 1–51.

[486] *Id.* at 1–61.

[487] *Id.* at 1–64, 1–65.

[488] *Id.* at 1–74. Various studies concerning prenatal and postnatal exposure of offspring demonstrated significant correlations with pregnancy and lactation. However, the report noted that further investigations are needed to more fully characterize the apparently significant effects of pregnancy on the disposition of TCDD and related compounds. *Id.*

[489] *Id.* at 1–82.

[490] PB-PK models incorporate known or estimated anatomical, physiological and physicochemical parameters in order to quantitatively describe the disposition of a particular chemical

have been developed for 2,3,7,8-TCDD in mice, rats and humans. These models have been effectively used to predict the disposition of TCDD and related compounds in the target species. In summary, these models have predicted results that approximate those found in actual studies, and may in the future prove valuable in assessing risks associated with the various parameters described above.

**Chapter 2. Mechanisms of Toxic Actions.**

The environmental contaminant 2,3,7,8-TCDD has generated worldwide concern because of its wide-spread distribution, its persistence, its accumulation within the food chain, and its toxic potency in experimental animals.[491] Epidemiological studies, however, have not produced a well-defined estimate of the risk that dioxin poses to human health.[492] For the future, knowledge of the mechanism of TCDD action may facilitate the risk assessment process by imposing constraints upon the assumptions used to estimate an acceptable exposure to dioxin.[493]

The challenge for risk assessment is to understand more fully the biochemical and genetic factors mediating the effects of dioxin in order to make it possible to set limits on acceptable human exposure. Given TCDD's widespread distribution, persistence and accumulation within the food chain, it is likely that most humans are exposed to some level of dioxin.[494] Therefore, the population at potential risk is multi-dimensional, and individuals are likely to vary in their susceptibility to dioxin, either because of genetic differences or because of exposure to other chemicals.[495] Further analyses of the mechanism of dioxin action may lead to methods of identifying those individuals who are especially at risk from exposure to TCDD.[496] For now, the paucity of information about the structure and function of the receptor[497]

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in a given species. *Id.* at 1–65. These models can assist in the extrapolation of dose kinetics within a species; estimate exposures by different routes of administration; calculate effective doses; and extrapolate the results across species. *Id.* Again, the details of these models are well beyond the scope of this article.

[491] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 2–1 (1992).

[492] *Id.*

[493] *Id.*

[494] *Id.* at 2–15.

[495] *Id.* Complex TCDD-induced effects (e.g., cancer) likely are the result of multiple steps and involve several genetic and/or environmental factors. Thus, only certain individuals may be at risk from exposure to TCDD, either because of their particular genetic makeup and/or their exposure to other chemicals.

[496] *Id.* at 2–15 to 2–16.

[497] Based on numerous studies, it is apparent that, given the extraordinary potency of TCDD in eliciting toxic effects, a receptor for dioxin exists. Biochemical and genetic evidence implicate the TCDD-binding protein—known as the Ah (dioxin) receptor—in the biological response to

which affects the biological response to dioxin represents the major barrier to a more complete understanding of the mechanism of dioxin action. In the future, a more complete understanding of the biochemical and genetic aspects of dioxin action should provide more insight into the mechanisms by which TCDD and related compounds produce birth defects, cancer and other public health concerns.

**Chapter 3. Acute, Subchronic, and Chronic Toxicity.**

The acute, subchronic, and chronic toxicology of the chlorinated dioxins, dibenzonfurans, biphenyl and related compounds has been the subject of recent reviews.[498] Chapter 3 summarizes the scientific community's knowledge of the toxicology of TCDD from experimental animal data and presents the complex picture which has evolved from these studies. The general conclusions of this chapter are briefly summarized below. Based on the reported studies, for acute toxicity, the range of doses for TCDD which are lethal to animals varied extensively both with species and strain, as well as with the sex, age, and the route of administration.[499] Typically, there is a delayed toxicity, with the time to death after exposure usually being several weeks.[500] However, deaths within the first week after exposure have been observed in some experimental animal groups.[501]

TCDD affects a variety of organ systems in different species, with the liver, thymus, and lymphatic tissues the most sensitive markers of toxicity.[502] However, it is not possible to specify a single organ whose dysfunction accounts for the lethality.[503] Dermal effects are prominent signs of toxicity in subhuman primates, and the formation of cutaneous lesions closely mimics the chloracne and hyperkeratosis observed in humans.[504]

Loss of body weight (wasting syndrome) is a characteristic sign observed in most animals given a lethal dose of TCDD.[505] The weight loss usually manifests itself within a few days after exposure and results in substantial reduction of adipose and muscle tissue.[506]

Finally, studies in some species indicate that the sensitivity to acute

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dioxin. *Id.* at 2–3. A summary of the biochemistry and function of the Ah receptor at the molecular level is beyond the scope of this article, but is fully described. *Id.*

[498] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 3–1 (1992).

[499] *Id.*

[500] *Id.*

[501] *Id.*

[502] *Id.* at 3–5.

[503] *Id.*

[504] *Id.*

[505] *Id.*

[506] *Id.*

toxicity of TCDD segregates with the Ah locus.[507] In addition, other studies with other dioxins and PCBs demonstrate that the potency for inducing lethality correlates with their ability to bind to the Ah receptor.[508]

For subchronic toxicity, the various studies overall are in agreement with those observed after administration of a single dose.[509] In addition, the limited data available indicates that signs and symptoms of subchronic toxicity follow the same rank order as Ah receptor-mediated effects.[510]

Finally, various long-term studies on TCDD indicate species-specific exposure levels leading to chronic toxicity.[511] Note that adverse effects have been observed at the lowest dose tested (roughly 2–3 ng/kg body weight).[512]

In summary, despite all the attention on this subject, the key event(s) underlying the mechanisms of toxicity have yet to be elucidated.[513] TCDD toxicity involves a variety of symptoms which vary from species to species and from tissue to tissue, both qualitatively and quantitatively.[514] In addition, age and sex differences have been reported. Polymorphism in the Ah locus, which is speculated to be the structural gene for the receptor, seems to determine the sensitivity of experimental animals to TCDD and congeners.[515]

**Chapter 4. Immunotoxic Effects.**

Extensive evidence has been accumulated during the past two decades that demonstrate that the immune system is a target for toxicity of TCDD and structurally related halogenated aromatic hydrocarbons (HAHs), including chlorinated dibenzofurans (CDFs), polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs).[516] Generally, the evidence suggests that there are multiple cellular targets within the immune system that are altered by

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[507] *Id.* at 3–9; *see also supra* note 497 and accompanying text for a brief overview of the Ah locus.

[508] *Id.*

[509] *Id.*

[510] *Id.* at 3–11.

[511] *Id.*

[512] *Id.*

[513] The toxicity of TCDD apparently depends on the fact that the four lateral positions of the molecule are occupied by chlorine, and toxicity correlates with the degree of substitution. *Id.* at 3–31.

[514] *Id.*

[515] *Id.* at 3–32. However, the role of the putative receptor requires further elucidation, and the available data suggests that the receptor for TCDD may be a prerequisite, but is not sufficient in itself for the mediation of toxicity. *Id.* at 3–33.

[516] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 4–1 (1992). This evidence was derived from numerous studies in

TCDD.[517] In parallel with the increased understanding of the cellular and molecular mechanisms involved in immunity, TCDD studies are beginning to establish biochemical and molecular mechanisms of TCDD immunotoxicity.[518]

The elucidation of a genetic basis for sensitivity to the toxicity of TCDD and related compounds is a fertile area of research in the study of HAH toxicity.[519] Current thinking is that many of the biochemical and toxic effects of HAH are mediated via binding to an intracellular protein referred to as the Ah or TCDD receptor.[520] The data relating HAH immunotoxicity, at least in part, to receptor-dependent events are convincing, but to date are not consistent across species.[521] And, despite numerous investigations, the specific cells that are altered by exposure to HAH leading to suppressed immune function have not been conclusively identified.[522]

Other TCDD effects are being analyzed. Results from host resistance studies provide evidence that exposure to TCDD results in increased susceptibility to bacterial, viral, parasitic and neoplastic disease.[523] These effects are observed at low doses and likely result from TCDD-induced suppression of immunological function.[524] There is also a reported increase in susceptibility of very young animals to HAH immunotoxicity following pre/neonatal exposure.[525]

Finally, the immunotoxicity of TCDD and related HAHs in humans has been the subject of numerous studies derived from accidental and/or occupational exposures to PCBs, PBBs, and TCDD.[526] How-

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various animal species, primarily rodents, as well as guinea pigs, rabbits, monkeys, marmosets, and cattle. *Id.* Epidemiological studies also provide evidence for the immunotoxicity of HAHs in humans. *Id.*

[517] *Id.* at 4–2.

[518] *Id.*

[519] *Id.* at 4–3. This area may one day provide a logical explanation for much of the controversial data regarding HAH toxicity among different species and in different tissues within a species. *Id.*

[520] *Id.* The speculation is that the process is similar to that of steroid hormone receptor-mediated responses. *Id.* Two lines of evidence have been used to investigate the Ah receptor-dependence of the acute immunotoxicity of TCDD and related HAH: (1) comparative studies using CDD, CDF and PCB congeners that differ in their binding affinity for the Ah receptor; and (2) studies using genetically different mice that are known to differ at the Ah locus. *Id.* at 4–4.

[521] *Id.* at 4–9. Based on the available data from mice, the majority of the immunotoxic effects of HAH appear to be mediated via the Ah receptor. *Id.* at 4–11.

[522] *Id.* at 4–14.

[523] *Id.* at 4–23.

[524] *Id.*

[525] *Id.* at 4–27.

[526] *Id.* at 4–33. Immunotoxic effects were described in Taiwanese patients who consumed acnegenic and hepatotoxic doses of PCDF-PCB contaminated rice oil in 1979 and in Michigan dairy farmers exposed to PBBs via contaminated dairy products and meat in 1973. *Id.* Clinical

ever, no clear pattern of immunotoxicity to HAH emerges from these studies in humans.[527] The basis for the lack of consistent, significant exposure-related effects is not known and may be dependent on several factors, including: characteristics of the assays used to examine immune function in humans exposed to TCDD and related HAHs; the use of data for individuals based on presumptive exposure rather than known, documented exposure; and the time separation between actual exposure and the assessment of immune function.[528] Clearly, further well-controlled animal studies are needed to assist in the establishment of no effect levels and acceptable exposure levels for human risk assessment for TCDD.

**Chapter 5. Reproductive and Developmental Toxicity.**

2,3,7,8-TCDD, one of seventy-five possible chlorinated dibenzo-p-dioxin (CDD) congeners, is one of the most potent of the compounds and serves as the prototype congener for investigating the toxicity of these classes of chemicals.[529] Reproductive and developmental toxicity is generally believed to be caused by the parent compound as there is no evidence that TCDD metabolites are involved.[530] However, humans are not exempt from the reproductive and developmental effects of complex HAH mixtures.[531] To date, the role of the Ah receptor mechanism, described above,[532] in producing signs of reproductive and developmental toxicity is not firmly established.[533]

TCDD has been shown to affect female reproductive end points in

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symptoms included respiratory tract and skin infections and reduced T-cell levels in blood. *Id.* In addition, another study reported the findings from immunologic assessment of 41 individuals from Missouri with documented adipose tissue levels of TCDD resulting from occupational, recreational or residential exposure. *Id.* at 4–34. Here, no adverse clinical disease was associated with TCDD levels in these subjects. *See id.* In addition, in a study on the immune status of 44 children, 20 of whom had chloracne, that were exposed to TCDD following an explosion at a herbicide factory in Seveso, Italy, no specific health problems were correlated with dioxin exposure in these children. *Id.* at 4–35.

[527] *Id.* at 4–35. In some cases, T-cell numbers increase; in others, they decrease. *Id.*

[528] *Id.* at 4–35 to 4–36.

[529] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 5–1 (1992).

[530] *Id.* The toxic potency of TCDD is due to the number and position of chlorine substitutions on the dibenzo-p-dioxin molecule. *Id.* CDD congeners with decreased lateral or increased non-lateral chlorine and bromine substitutes are less potent than TCDD. *Id.*

[531] *Id.* A mechanism of action which CDD, BDD, CDF, BDF, PCB, and PBB congeners substituted in the lateral position have in common is that they bind to the Ah receptor which then binds to a translocating protein that carries the activated TCDD receptor complex into the cell's nucleus. These activated TCDD receptor complexes bind to specific sequences of DNA (referred to as dioxin-responsive enhancers or DREs), resulting in alterations of gene transcription. *Id.* at 5–2.

[532] *See supra* note 497 and accompanying text.

[533] *See supra* note 531, at 5–2.

a variety of animal studies, including reduced fertility, reduced litter size, and effects on the female gonads and menstrual/estrous cycle.[534] In males, TCDD and related compounds decrease testis and accessory sex organ weights, cause abnormal testicular morphology, decrease spermatogenesis, and reduce fertility when given to adult animals in doses sufficient to reduce feed intake and/or body weight.[535]

The results of developmental toxicity were divided into three categories for ease in assessing the data base with respect to an Ah-receptor mediated response: death/growth/clinical signs; structural malformations; and functional alterations.[536] Exposure related effects on death/growth/clinical signs along with structure activity results that are consistent with, *but do not prove*, an Ah-receptor mediated mechanism are described for a variety of test organisms[537] and humans.[538] Developmental effects (such as cleft palate, hydronephrosis[539] and

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[534] *Id.* at 5–2.

[535] *Id.* at 5–11.

[536] *Id.* at 5–14 to 5–15.

[537] *Id.* at 5–15. Early life stages of fish appear to be more sensitive to TCDD-induced mortality than adults. This is suggested by the $LD_{50}$ of TCDD in rainbow trout sac fry (0.4 ug/kg egg weight) being 25 times less than that in juvenile rainbow trout (10 ug/kg body weight). *Id.* TCDD is directly toxic to early life stages of fish as demonstrated by Japanese medaka, pike, rainbow trout, and lake trout exposed as fertilized eggs to graded concentrations of waterborne TCDD. *Id.* Lake trout are the most sensitive of fish species to TCDD developmental toxicity. *Id.* at 5–16. Although the Ah receptor has not been identified in early life stages of fish, it is presumed to be present based on inducement experiments. *Id.* The Ah receptor has been identified in some adult fish species. *Id.*

Bird embryos are also more sensitive to TCDD toxicity than adults. The $LD_{50}$ of TCDD in chicken embryos (0.25 ug/kg egg weight) is 100–200 times less than the TCDD dose that causes mortality in adult chickens (25–50 ug/kg body weight). *Id.* There is also evidence in chicken embryos that the Ah receptor may be involved in producing developmental toxicity. *Id.* at 5–17.

Laboratory animals exposed to TCDD during adulthood display wide differences in the $LD_{50}$ of TCDD. *Id.* at 5–20. It appears that the magnitude of the species differences in lethal potency of TCDD is affected by the timing of TCDD exposure during the life history of the animal. *Id.* at 5–21. Exposures to TCDD during pregnancy cause prenatal mortality in the monkey, guinea pig, rabbit, rat, hamster, and mouse. *Id.* The structure activity relationship for developmental toxicity in laboratory mammals is generally similar to that for Ah receptor binding. *Id.* at 5–29.

[538] Developmental toxicity has been reported in human babies born to affected mothers who consumed rice oil contaminated with PCBs, CDFs and others. *Id.* at 5–29. High mortality was observed among infants born to affected mothers who themselves did not experience increased mortality. *Id.* at 5–30. Thus, in humans, the developing embryo/fetus may be more sensitive than the mother to mortality caused by HAHs. *Id.* In most cases, women who had affected children had chloracne themselves. *Id.*

Effects of chemical exposure on normal development of the human fetus can have four outcomes depending on the dose and time during gestation when exposure occurs: fetal death, growth retardation, structural malformations, and organ system dysfunction. *Id.*

[539] In mice, hydronephrosis is the most sensitive developmental response elicited by TCDD, and is characterized as a progressive occurrence in the right kidney which can be accompanied by hydroureter and/or abnormal nephron development. *Id.* at 5–44 to 5–45.

other structural malformations) following exposure to halogenated dibenzo-p-dioxin, dibenzofuran and other compounds have been clearly demonstrated and provide the most convincing evidence of an Ah receptor-mediated response.[540] Susceptibility to the developmental actions of TCDD in mice depends on two factors: fetus genotype and developmental stage at time of exposure.[541] Differences exist among mammalian species with respect to susceptibility to the developmental effects of TCDD.[542] With respect to the occurrence of similar developmental effects in mammalian species other than the mouse, for the most part no other species develops these structural malformations except at maternal doses that are fetotoxic and maternally toxic.[543] Studies in humans *have not* clearly identified an association between TCDD exposure and structural malformations.[544]

Postnatal functional alterations, such as on the male reproductive system, have also been demonstrated for some experimental animals.[545] It also appears that perinatal exposure to TCDD impairs sexual differentiation of the central nervous system which leads to demasculinization and feminization of sexual behavior.[546] The male reproductive system in rats is approximately 100 times more susceptible to TCDD toxicity when exposure occurs perinatally rather than in adulthood.[547]

The effects of TCDD on neurobehavior were also studied since the central nervous system is a highly differentiated tissue that derives

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[540] *Id.* at 5–32 to 5–47. These compounds bind stereospecifically to the Ah receptor as shown in several studies. *Id.* at 5–37 to 5–44.

[541] *Id.* at 5–32. As noted above, the Ah receptor is thought to mediate the developmental effects of TCDD. *Id.*

[542] *Id.* at 5–33.

[543] *Id.* at 5–35. Note that, in mice and hamsters, hydronephrosis can be elicited at TCDD doses that are neither fetotoxic nor maternally toxic. *Id.*

[544] *Id.*

[545] *Id.* at 5–47 to 5–65. TCDD exposure is expected to have a great impact on the male reproductive system in rats during early development. *Id.* at 5–47. For example, decreased spermatogenesis was among the most sensitive responses of the male rat reproductive system to perinatal TCDD exposure. *Id.* at 5–51. Although perinatal TCDD exposure had little or no effect on fertility of male rats or on survival and growth of offspring, it is known that rats produce and ejaculate ten times more sperm than are necessary for normal fertility and litter size. *Id.* at 5–55. Note that, in contrast, reproductive efficiency in *human males* is very low with the number of sperm per ejaculate being close to that required for fertility. Thus, a percent reduction in daily sperm production for humans, similar in magnitude to that observed in rats, may reduce fertility. *Id.*

[546] *Id.* at 5–56 to 5–60.

[547] *Id.* at 5–61.

from ectoderm during development.[548] The results of these studies on mice and monkeys demonstrated a range of neurobehavioral effects. In humans, the intellectual and behavioral developments of children transplacentally exposed to PCBs, CDFs, and other compounds were studied.[549] Effects such as developmental or psychomotor delay, speech problems, reduced scores on developmental and cognitive tests, and lagging intellectual development were shown.[550] These studies show that, in humans, transplacental exposure to HAHs can affect central nervous system function postnatally.

**Chapter 6. Carcinogenicity of TCDD in Animals.**

There is an ever increasing amount of scientific information relevant to the use of animal cancer data for the estimation of human risks than was available during the early studies in 1988.[551] However, much of the tumor incidence data in experimental rats and mice was available to show that TCDD is a carcinogen at multiple sites, including the occurrence of cancers following low doses.[552] New research confirms these findings for hamsters, and the data from early studies has been reevaluated.

In this chapter, new information from seventeen long-term (chronic) bioassays for carcinogenicity that were designed to determine if TCDD is a carcinogen in experimental animals demonstrate that TCDD: (1) is a multisite carcinogen; (2) is a carcinogen in both sexes and in several species of experimental animals; (3) is a carcinogen in sites remote from the site of treatment; and (4) increases cancer incidence at doses well below the maximum tolerated dose (MTD).[553]

This chapter notes that several studies in the past few years have provided increased understanding of the biochemistry of the carcinogenicity of TCDD in animals. A general consensus has emerged that most, if not all, of TCDD's biochemical and toxic effects require interaction with the Ah receptor.[554] However, it is apparent that the for-

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[548] *Id.* at 5–62 to 5–65.

[549] *Id.* at 5–64 to 5–65.

[550] *Id.* at 5–64. Such children were rated by their parents and teachers to have a higher activity level, more health, habit and behavioral problems, and a temperamental clustering close to that of a "difficult child." *Id.*

[551] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 6–1 (1992).

[552] *Id.*

[553] *Id.* at 6–37. The details of these studies are beyond the scope of this article.

[554] *Id.* at 6–1. The properties of the Ah receptor and the mechanisms whereby this receptor regulates gene expression are the subject of other chapters and are discussed elsewhere. *See supra* notes 497, 507–10 and accompanying text.

mation of the Ah receptor-TCDD complex is but the first step of many in the production of a toxic effect.[555] The general consensus is that TCDD is an example of receptor-mediated carcinogenesis in that: (1) interaction with an Ah receptor appears to be a necessary early step; (2) TCDD modifies a number of receptor and hormone systems involved in cell growth and differentiation; and (3) hormones exert a significant influence on the carcinogenic actions of TCDD.[556]

The key issues in the risk assessment of TCDD and its related compounds include: (1) characterization of the shape of the dose-response curve for receptor-mediated events;[557] (2) evaluation of the relevance of animal data in the estimation of human risks;[558] and (3) the health consequences of background exposures of dioxin and its structural analogs.[559] Much of the controversy surrounding dioxin risk assessment reflects the selection of methods of analysis. Given the increased knowledge about the mechanism of dioxin action, the construction of biologically-based models which remove some of the uncertainty in current risk assessments may soon be possible. Overall, it appears that several studies indicate that in terms of biochemical and carcinogenic effects, humans apparently respond in a similar manner as experimental animals.[560]

**Chapter 7. Epidemiology/Human Data.**

*A. Cancer Effects.*

As noted in this chapter, while bioassay data from experimental animals provide substantial presumptive evidence of human carcino-

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[555] *Id.* at 6–2.

[556] *Id.* at 6–37.

[557] The evaluation of dose-response is one of the most important issues associated with dioxin risk assessment. Apparently the focus of the studies centers on whether the effects of dioxin will exhibit a threshold or not. *Id.* at 6–2. For some responses, there is a proportional relationship between receptor occupancy and response as evidenced by a linear relationship between dose and effect over a wide dose range. *Id.* However, it is clear from animal studies that there are different dose-response curves for different TCDD effects which is consistent with the general findings for steroid receptor-mediated responses. *Id.* at 6–38. Thus, it is inappropriate to use a single marker to estimate dioxin's risks. *Id.* at 6–2. Finally, the data indicate that there is no common dose-response relationship for all Ah receptor-mediated responses. *Id.*

[558] Whether experimental animal models are relevant for estimating human risks is a very controversial area in risk assessment. *Id.* at 6–2. Recently, there has been increasing evidence that biochemical and toxic responses resulting from exposure of humans to TCDD and related compounds appear to be similar to the responses seen in animal experiments. However, the mechanistic basis for interindividual variation has not been ascertained, and this lack of knowledge complicates approaches to estimating human risks from experimental animal data. *Id.* at 6–38.

[559] *Id.* at 6–37 to 6–38.

[560] *Id.* at 6–38. However, data from epidemiology studies are difficult to evaluate because the carcinogenic effects, if any, from background TCDD exposures are not known. *Id.*

genicity of TCDD, actual verification must, of course, come from human studies.[561] Based on the results from animal studies, expected target organs include the liver, thyroid, lungs, skin and soft tissues. This chapter reports on the cancer epidemiology evidence of TCDD and its congeners. The original research reports are organized and discussed in four groups: (1) follow-up studies of chemical manufacturing and processing workers;[562] (2) case-control studies in general populations; (3) studies of pulp and paper mill workers; and (4) other studies (including studies of pesticide applicators, Vietnam veterans with potential exposure to Agent Orange, residents of Seveso, Italy exposed to TCDD during an accidental explosion, and victims of contaminated rice oil poisonings).[563] These are summarized below.

(1) Follow-up studies of chemical manufacturing and processing workers.

A study in the United States examined 5,172 persons who had worked at twelve plants involved in the production of chemicals contaminated with TCDD.[564] Follow-up began in 1940 or on the date of the first systematically documented assignment to a process involving TCDD contamination, whichever was later, and closed at the end of 1987.[565] Statistical comparisons were made with the U.S. population.

Approximately thirteen percent of the workers had records of chloracne, the presence of which is an indicator of relatively intense exposure to TCDD (or higher-chlorinated PCDDs as well).[566] Statistically significant results indicate that the group as a whole experienced an estimated fifteen percent elevation of mortality from all cancers combined, with a fifty percent elevation among those workers in a long duration/latency subgroup.[567] An excess of deaths from cancers

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[561] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 7–1 (1992).

[562] These follow-up studies are important because they contain sizable groups of humans with substantial TCDD exposures.

[563] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 7–1 (1992). As stated in the chapter, a major weakness in almost all studies is the lack of reliable exposure information. Most studies rely on interviews and questionnaires of work history to ascertain exposure surrogates. There is little, if any, verification of actual internal exposure to these compounds. *Id.* at 7–2.

[564] *Id.* at 7–7.

[565] *Id.*

[566] *Id.*

[567] *Id.* at 7–8. Among the total 5,172 workers, special attention was paid to results for 3,036 workers who were followed at least 20 years after the first exposure. This group was divided into those with less than one year exposure (n=1,516) and those with more than one year exposure (n=1,520). Those workers with more than one year exposure are referred to as the "long duration/latency" subgroup. *Id.*

of connective and soft tissues (known as soft-tissue sarcomas or STSs) was apparent.[568] A forty percent overall elevation in deaths from non-Hodgkin's lymphoma was also observed.[569] Results for Hodgkin's disease were highly imprecise, based on only three deaths. Lung cancer was elevated by ten percent overall and by forty percent in the long duration/latency subgroup.[570] A similar forty percent excess of stomach cancer in the subgroup was based on only four deaths; no excess was observed in the total group.[571]

A German study utilized 1,583 males and females employed at a chemical manufacturing facility that produced 2,4,5-T and its precursor, 2,4,5-trichlorophenol.[572] The authors of the study, who presented detailed analyses only for all cancers combined, concluded that "the increase in (total) cancer risk of 1.24–1.39 . . . cannot be explained completely by confounding factors, and . . . is associated with exposure to TCDD."[573] Another smaller German study also reported an increased cancer risk of 1.2.[574] Other studies are reported,[575] but are not reviewed in any depth in this chapter.

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[568] *Id.* Note that these results were based on only four deaths (and three deaths for the long duration/latency subgroup) from two different plants. *Id.*

[569] *Id.*

[570] *Id.* at 7–8. Confounding by cigarette smoking must be considered in interpreting the approximate 40 percent excess of lung cancer deaths in the long duration/latency subgroup. *Id.* at 7–9. This leads to the conclusion that cancers of the respiratory tract *may* result from exposure to TCDD, although the possibility of contribution from factors such as smoking and exposure to other industrial chemicals cannot be excluded. *Id.*

[571] *Id.* at 7–8.

[572] *Id.* at 7–10. In 1954, a chloracne outbreak occurred in the working population of the plant. Subsequently, production of the TCDD contaminant was reduced. Study group members worked at least three months from 1952 through 1984. Follow-up presumably began on the date of accumulation of three months of employment and closed at the end of 1989. Mortality was compared with that of the West German population (and with a group of workers at a gas supply company, although these data are not reported because there were no material differences between the analyses). *Id.*

[573] *Id.* at 7–11 (quoting Manz *et al.*, *Cancer Mortality Among Workers in Chemical Plant Contaminated With Dioxin*, 338 LANCET, 959–64 (1991)). For the group, estimated relative risk of lung cancer was 1.4 and relative risk of stomach cancer was 1.2. *Id.* It is interesting to note, albeit inconclusive, that the relative risk for breast cancer among the female workers was 2.2. *See id.* at 7–12.

[574] *Id.* at 7–12.

[575] Another ten-country historical study was conducted by the International Agency for Research on Cancer (IARC). This study looked at cancer mortality in 18,390 production workers or sprayers exposed to chlorophenoxy herbicides and/or chlorophenols. Exposure was reconstructed through questionnaires, factory or spraying records, and job histories. *Id.* at 7–13. Although increased cancer risks were observed, the lack of better exposure information, and the small numbers limit the author's confidence to make conclusions. *Id.* at 7–14. In addition, Danish and British scientists conducted studies of exposed workers, but again exposure information was not sufficient to permit reasonable interpretations. *Id.* at 7–15 to 7–16.

(2) Case-control studies in general populations.

Case-control studies of soft-tissue sarcomas (STSs) and of malignant lymphomas are reported from Sweden,[576] the United States,[577] New Zealand,[578] and Italy.[579]

In summary, from the standpoint of exposures to TCDD, the most important results from general population case-control studies come

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[576] In northern Sweden, most exposures occurred in the use of 2,4,5-T and 2,4-D in combination in forestry applications, often by knapsack spraying. *Id.* at 7–18. Phenoxy acid exposures not involving 2,4,5-T were proportionally more common in the central and southern regions in which agricultural herbicide uses predominated. *Id.*

[577] Researchers at the National Cancer Institute reported results from three case-control studies in four Great Plains states (Kansas, Nebraska, Iowa and Minnesota). *Id.* at 7–23, 7–24. Only the study in eastern Nebraska suggests an increase in risk due to 2,4,5-T. *Id.* at 7–24. Another study of STSs and non-Hodgkin's lymphomas was conducted in western Washington state. *Id.*

> The results of this study show no association between soft-tissue sarcomas or non-Hodgkin's lymphomas and estimated potential for exposure to phenoxy acids or chlorophenols. The authors did report, however, that the relative risk of non-Hodgkin's lymphomas associated with more than 15 years of potential exposure to phenoxy acids increased with time since the accumulation of that exposure. The relative risk estimates were 1.3 for exposures more than five years before diagnosis, 1.7 for more than 15 years, and 2.5 for more than 25 years. Similar trends were not observed in any analyses of STSs and phenoxy acids or of either cancer in connection with chlorophenol exposure.

*Id.* at 7–25. It is noted that the major problem with the U.S. case-control studies is that specific exposure to TCDD and related compounds is not identified or quantified. *Id.* at 7–26.

[578] Two studies of SRSs and one study of non-Hodgkin's lymphomas among men were conducted in New Zealand. *Id.* at 7–26. Because 2,4,5-T was widely used as a phenoxy acid herbicide (e.g., for spraying of gorse, blackberry, pasture, cereal, and peas) in New Zealand over the years relevant to their studies, the phenoxy acid exposure designation was considered a suitable indicator of exposure to 2,4,5-T and thus to TCDD. *Id.* The authors of the study emphasized that herbicide spraying is a full-time occupation in New Zealand and that none of the SRS or malignant lymphoma cases were commercial sprayers. *Id.* at 7–28 to 7–29. Relative risk estimates ranged from 1.3 for any "potential" exposure to 1.6 for exposures ("definite or probable" for phenoxy acids, "potential" for chlorophenols) lasting more than one day and occurring more than five years prior to diagnosis. *Id.* at 7–27 to 7–28. The estimated relative risk was 3.0 among farmers for phenoxy acid exposures. *Id.* at 7–28.

[579] Researchers conducted a case-control study of SRSs in three provinces in northern Italy. Phenoxy acid exposure classifications were based on job information provided in interviews or questionnaires. *Id.* at 7–30. Although the authors implied that phenoxy acid herbicides of all types (2,4-D, 2,4,5-T, and MCPA) were used in the area during the crucial time period, they were only able to document use of 2,4-D and MCPA, which do not contain dioxin and dibenzofuran impurities. *Id.* Thus, this study appears to have limited relevance to concerns for TCDD exposures. *Id.* The study indicated an inverse association between possible or certain phenoxy acid exposure and SRS risk among men, and a positive association among women. *Id.* Rice is the principal agricultural crop in the study area, and rice weeding was predominately a female occupation. Rice weeding during this period (1950–55) was manual and contact with the phenoxy herbicides was mainly dermal. *Id.* at 7–31. Among all women in the study, rice weeding during the early 1950s is associated with a relative risk of 2.3. *Id.*

from those conducted in Sweden and New Zealand.[580] These studies all were conducted in areas in which high proportions of phenoxy acid exposures involved 2,4,5-T.[581] For STSs, the Swedish studies indicated a relative risk of 2.3 for phenoxy acids among workers in agriculture, horticulture, and forestry.[582] The relative risk estimate of 3.0 for phenoxy acid exposure among farmers in New Zealand appears to indicate that farming may be a confounder in the study.[583]

For malignant lymphomas, the case-control studies provide little evidence of a positive association.[584] Most of the studies (New Zealand, Kansas, Nebraska, and Iowa and Minnesota) indicate a small increase in risk, or no increase at all, from exposures to TCDD.[585]

(3) Studies of pulp and paper mill workers.

Three studies of pulp and paper mill workers are summarized.[586] These studies are important because of the potential for exposure to PCDDs in these occupations. These studies did not indicate appreciable increases in the risk of non-Hodgkin's lymphomas, lung cancer, or stomach cancer among pulp and paper mill workers.[587] Overall, the rate of all cancers combined was lower than expected.[588]

(4) Other studies.

Studies of the distribution of TCDD levels in serum and adipose tissue of Vietnam veterans were indistinguishable from comparison populations *except* where the Vietnam veteran group was carefully defined on the basis of military records to have engaged in activities known to have involved herbicide exposure.[589] There has been a small mortality study of 1,261 Air Force veterans who were responsible for aerial herbicide spraying missions (known as Operation Ranch Hand) in Vietnam.[590] A total of twenty-five cancer deaths were observed, for

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[580] *Id.* at 7–31.

[581] *Id.* Moreover, for most of these studies, available data allow analyses restricted to farmers and other occupational categories within which the relevant exposures predominantly occur. *Id.*

[582] *Id.*

[583] *Id.* Indirect standardization for farming reduces the relative risk to 1.9. *Id.*

[584] *Id.* at 7–32.

[585] *Id.*

[586] These studies included: (1) 3,572 persons who had worked for at least one year between 1945 and 1955 at any of five mills in the states of California, Oregon or Washington; (2) 3,454 Finnish workers in the pulp and paper industry who had worked continuously for at least one year between 1945 and 1961; and (3) 883 persons who had worked for at least one year at a mill in New Hampshire. *Id.*

[587] *Id.* at 7–33.

[588] *Id.*

[589] *Id.* at 7–34. Thus, the designation "Vietnam veteran" is insufficient as an indicator of exposure to 2,4,5-T or TCDD exposure. *Id.*

[590] *Id.* at 7–35.

a relative risk of 1.1. Rates of all specific cancers of interest were equal to or less than the rates in the comparison group.[591]

Another study examined residents of Seveso, Italy who were exposed to 2,3,7,8-TCDD from a chemical accident in 1976. High exposures were indicated, with approximately 200 chloracne cases reported.[592] However, because the population has only been followed for ten years, results do not yet support a meaningful analysis of cancers.[593] To date, no excesses of mortality from lung cancer, stomach cancer, or all cancers combined, are apparent.[594] More meaningful information concerning cancer effects will not be available until additional time since first exposure has elapsed.[595] Finally, two incidents involving contamination of ingested food from PCBs and polychlorinated dibenzofurans (PCDDs) are discussed.[596] In 1968, 1900 people (termed the "Yusho" incident) accidentally consumed up to two grams each of PCBs[597] that had leaked into the rice oil at the canning facility. The victims suffered many ill effects from the single exposure.[598] The most significant finding was a greatly increased risk of liver cancer and of lung cancer in male victims.[599] In 1979, a similar outbreak of illness was reported among 2,000 persons in Taiwan (termed the "Yu-Cheng" incident).[600] This outbreak consisted of chloracne and other symptoms.[601] Non-cancer toxic effects resulting from the transplacental exposure to the cooking oil in children born to exposed

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[591] *Id.*

[592] *Id.* The group residing in the zone of highest estimated exposure consists of 566 adults and 306 children. The group residing in a zone of intermediate estimated exposure consists of 3,920 adults and 2,727 children. *Id.* at 7–36. The group with lowest exposure consists of 26,227 adults and 16,604 children. *Id.* However, the accuracy of this exposure classification has been questioned because it does not correspond to the occurrence of chloracne reported. *Id.*

[593] *Id.*

[594] *Id.*

[595] *Id.*

[596] PCBs and PCDFs are structurally similar to the polychlorinated dioxins, and some are considered to be dioxin-like in their activity. *Id.* at 7–37. All these related and analogous compounds—the dioxin-like polychlorinated biphenyl congeners, the 75 chlorinated dioxins and 135 chlorinated dibenzofurans—appear to induce similar effects in both animals and humans, but seem to differ quantitatively in toxicity. They appear to harm growth and reproduction, damage the immune system, and cause cancer. *Id.*

[597] *Id.* at 7–37. The PCBs were primarily Kanechlor 400 that had been used as a heat exchange medium thousands of times. *Id.* Commercially prepared Kanechlor 400 had a concentration that was 49 percent chlorinated. *Id.*

[598] *Id.* at 7–37. The ill effects are attributed to the retention of PCBs and PCDFs, for many years after the initial exposure, as indicated by tissue studies. Researchers attribute these effects to the presence of PCDFs, although PCB exposure produces similar effects. *Id.*

[599] *Id.* at 7–38.

[600] *Id.* at 7–38. Subsequently, the illness was traced to the ingestion of cooking oil contaminated with PCBs. *Id.*

[601] *Id.*

mothers include: shorter and lighter children with developmental abnormalities, as well as developmental and behavioral deficiencies.[602] Information concerning cancer effects is not available due to inadequate time passage.

In conclusion, based on all the cancers examined in the studies described above, soft-tissue sarcomas (STSs) provide the strongest evidence of an association with TCDD.[603] The evidence on malignant lymphomas in connection with TCDD exposure is far less compelling, with evidence of increased risks for lung cancer and stomach cancer associated with TCDD exposure.[604]

*B. Health Effects Other Than Cancer.*

Briefly, the most frequently described effects on humans from exposure to 2,3,7,8-TCDD involve the skin, and liver and neurologic systems.[605] Other effects include disturbances of the gastrointestinal, genitourinary, endocrine, respiratory, cardiovascular, pulmonary, and immunologic systems, as well as increases in the incidence of some malignancies.[606] The majority of effects have been reported among occupationally-exposed groups.[607] These groups include chemical production workers, pesticide users, and individuals handling or exposed to materials that have been treated with 2,3,7,8-TCDD-contaminated pesticides.[608]

**Chapter 8. Dose-Response Relationships.**

This chapter focuses on dose-response modeling for 2,3,7,8-TCDD.[609] Specifically, the chapter presents the current thinking on TCDD mechanistic action and focuses on dose-response models for cancer in experimental animals and humans. Although the details of this chapter are beyond the scope of this article, it is useful to summarize that, as evidenced by the discussion of the preceding chapters, considerable information is now available on the mechanisms of action responsible for TCDD's effects in experimental animals and humans. However, there are several knowledge gaps that remain to be resolved. Existing data and future experiments are essential to the development of reliable biologically-based models for the estimation of human risks associated with exposure to TCDD and related compounds.

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[602] *Id.* at 7–39.

[603] *Id.*

[604] *Id.* at 7–40 to 7–42.

[605] *Id.* at 7–68.

[606] *Id.* at 7–68. The details of these health effects are fully described at 7–68 to 7–95.

[607] *Id.* at 7–68.

[608] *Id.*

[609] U.S. EPA, HEALTH ASSESSMENT FOR 2,3,7,8-TETRACHLORO-DIBENZO-P-DIOXIN (TCDD) AND RELATED COMPOUNDS 8–1 (1992).