Chapter 3

Incinerable Hazardous Waste: Characteristics and Inventory

Contents

Box

Tables

Figures

Chapter 3

Incinerable Hazardous Waste: Characteristics and Inventory

CHARACTERIZING INCINERABLE WASTE

Waste Properties

Any discussion of the quantities of hazardous waste that could be incinerated on land or at sea must start by considering characteristics of both the waste and the technologies for incineration. This section identifies and discusses the most important characteristics of incinerable wastes, relating them to the requirements or restrictions of available incineration technologies.

Generally, only organic wastes or other wastes with significant organic content are considered appropriate for incineration, which excludes all inorganic materials. [1] Other important attributes of waste include energy content, physical form, the presence of hazardous constituents or properties, and chlorine and metal content.

Energy Content

An important characteristic that influences a waste's suitability for incineration is energy content (usually expressed in British thermal units, or Btu). Efficient thermal destruction of the organic portion of a waste requires that the entire mixture being incinerated have some minimum energy content. Therefore, many incinerable wastes must be blended with, or burned in the presence of, auxiliary fuel or high-energy waste to ensure complete destruction. Other incinerable organic wastes have sufficient energy content to maintain their own combustion, enhancing both the efficiency and cost-effectiveness of incineration.

Many common wastes represent mixtures of organic and inorganic materials. The organic fraction of such wastes, no matter how small, is at least technically incinerable. For example, the Environmental Protection Agency (EPA) recently used a mobile incinerator to destroy dioxin-tainted soil in Times Beach, Missouri. Four pounds of dioxin contained in 40 tons of soil were successfully destroyed by using auxiliary fuel to heat the soil to a sufficient temperature (20). However, for more routine operations, and particularly for commercial incineration, the cost of incinerating wastes with extremely low organic content would probably be prohibitive.

Physical Form

Different incineration technologies have developed for handling the various physical forms (solid, sludge, liquid, and gas) of hazardous organic wastes (see ch. 5).

Incinerable wastes that are candidates for ocean incineration generally fall into the category of ***liquid*** organic wastes. Only wastes in liquid form are suitable for the liquid injection technology used by all incineration vessels built or planned to date. Liquid injection technology has the advantage of large capacity but can only handle wastes that can be pumped and be introduced into the incinerator in the form of small droplets. [2]

A significantly broader range of waste forms is considered incinerable on land than at sea, because land-based facilities can employ a broader range of incineration technologies. Most commercial land-based incineration facilities use rotary kiln technology, which can incinerate organic ***solids and sludges,*** as well as liquids (25). Some existing rotary kilns can even incinerate solid waste contained in 55-gallon steel drums (l).

The presence of water in wastes can be either an advantage or a disadvantage with respect to their incinerability. Generally, aqueous (water-contain-

[1] The term ***organic*** refers to chemical substances that possess a molecular skeleton made of carbon and hydrogen and that generally contain only a few other elements, such as nitrogen, oxygen, or chlorine. ***Inorganic*** materials are generally composed of or contain metals.

[2] Certain solid or sludge wastes that can be suspended in liquid waste to render them pumpable could also be incinerated at sea.

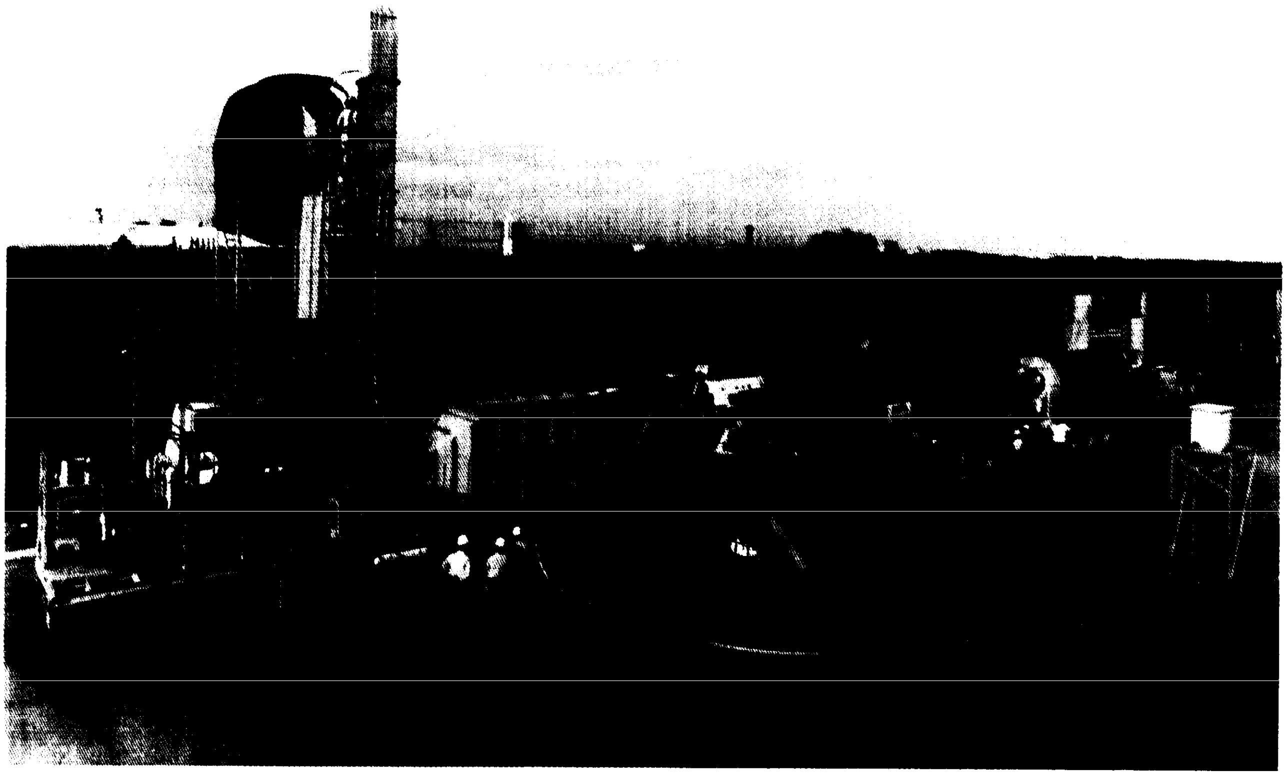

Photo credit: Air Pollution Control Association/EPA

A mobile incinerator, used by the U.S. Environmental Protection Agency to destroy wastes contaminated with dioxin, A mobile system can be transported to hazardous waste sites, thereby eliminating the need to transport wastes.

ing) wastes are not considered particularly amenable to incineration, because more energy is needed to heat and evaporate the water. If an aqueous waste also contains organic material with a very high energy content, however, the presence of water can actually prevent overheating and increase the rate at which wastes can be incinerated.

Hazardous Constituents or Properties

The vast majority of incinerable liquid wastes are subject to regulation as hazardous waste under the Resource Conservation and Recovery Act (RCRA) or certain State statutes. This designation may be based either on the presence of particular toxic components or on a generic characteristic of the waste (e.g., ignitability). In addition to incinerable wastes classified as hazardous, a few nonhazardous liquid wastestreams are amenable to incineration. For example, alcohol-based portions of some pharmaceutical and pesticide wastes are incinerable but not classified as hazardous (l).

Liquid organic wastes are derived from a wide variety of industrial processes and sources and, therefore, can contain an enormous number of chemical constituents. One profile undertaken by EPA identified over 400 distinct hazardous wastestreams being incinerated in land-based facilities (12). These wastes contained 237 different constituents, 140 of which were listed as hazardous under RCRA. Table 1 summarizes those constituents that were most commonly found and those that were incinerated in the greatest amounts.

A second EPA profile of existing hazardous waste incinerators used RCRA hazardous waste codes (40 CFR 261, Subpart D) to classify wastes currently being incinerated in land-based facilities. This study (10) found that the most frequently reported wastes were nonlisted ignitable (RCRA Code DOO1) with high energy content and high concentrations of hazardous constituents. The waste category representing the largest annual quantity of incinerated waste, however, was spent nonhalogenated solvents (F003). The next most common categories contained sufficient water to be considered ***aqueous*** wastes. These included the following:

- aqueous corrosives (DO02),
- aqueous reactives (DO03),
- aqueous ignitable (DOO1) with low energy content and low concentrations of hazardous constituents,
- wastewater from acrylonitrile production (KO11), and
- hydrocyanic acid (P063).

Most of these aqueous wastes are considered poorly suited for recycling and recovery and are generated in quantities too large to be economically shipped for offsite disposal. Therefore, the wastes are generally managed—by using underground injection or, where possible, incineration—at the facilities where they were generated. Such wastes would be unlikely candidates for ocean incineration.

Table 1 .—**Most Common and Most Abundant Chemical Constituents Found in Incinerated Hazardous Wastestreams**

Five most commonly identified constituents	Five constituents incinerated in the greatest amounts
1. Toluene	1. Methanol
2. Methanol	2. Acetonitrile
3. Acetone	3. Toluene
4. Xylene	4. Ethanol
5. Methyl ethyl ketone	5. Amyl acetate

SOURCE: Mitre Corp., *Composition of Hazardous Waste Streams Currently Incinerated,* contract report prepared for the US. Environmental Protection Agency, Office of Solid Waste (Washington, DC: April 1983).

Chlorine Content

Many liquid wastes considered especially amenable to ocean incineration contain relatively high amounts of organically bound chlorine.

Energy content is inversely related to chlorine content, which means that the heat value of wastes decreases as chlorine content increases.

Thermal destruction of chlorinated wastes by incineration generates highly corrosive and toxic hydrogen chloride gas. Land-based facilities are required to have air pollution control equipment (i. e., scrubbers) capable of removing and neutralizing acid gases, if wastes with significant chlorine content are to be incinerated (47 FR 27520, June 24, 1982). The proposed Ocean Incineration Regulation (50 FR 8222, Feb. 28, 1985) does not require the use of scrubbers on ocean incinerator vessels, because of seawater's natural capacity to neutralize hydrogen chloride gas, and because the vessels operate far away from human populations.[3]

Several factors act to place a practical limit on the chlorine content of wastes that can be incinerated in land-based facilities, as discussed in chapter 1. These factors include:

- limitations on the practical size and capacity of scrubbers for removing hydrogen chloride gas;
- the increase in the quantity and corrosivity of hydrogen chloride emissions as the chlorine content of wastes increases, which can damage the incinerator or scrubber system; and
- the generation of chlorine gas (1 3,28), which is not efficiently removed by stack scrubbers and could pose risks from direct inhalation by nearby human populations.

For these and other reasons, the chlorine content of hazardous wastes can strongly influence the range of available management options. Wastes of intermediate chlorine content can in some cases be burned in cement kilns and other industrial furnaces, where corrosive gases are directly used in the production process. Although there appears to be an enormous available capacity for *burning* such wastes in these facilities, the reluctance of many fur-

[3]For a number of reasons, incineration of highly chlorinated wastes at sea may be advantageous (see ch. 1).

nace operators to use the wastes as fuel, the relative lack of regulation and rigorous environmental testing of the practice, and practical limits on acceptable chlorine content, are obstacles to its greater application (2,5,17). See chapter 4 for a detailed discussion of the burning of hazardous wastes in industrial boilers and furnaces.

Metal Content

In contrast to the organic component of hazardous wastes, metals are not destroyed by incineration. Metals present in waste fed to an incinerator are either deposited in the ash residue left behind in the chamber or emitted in stack gases. Most metals that leave the incinerator stack are in the form of particulate matter and can be captured by stack scrubbers,[4] Particulate and associated metals are deposited in the sludge generated by the operation of the scrubber. Ash and sludge residues from hazardous waste incineration are generally classified as hazardous waste and must be handled accordingly.

Although metals are not destroyed by incineration, high temperatures can alter the physical and chemical forms of metals, thereby affecting their subsequent fate and behavior, For example, certain toxic metals (e. g., arsenic and selenium) are volatilized (i. e., changed into gas form) during incineration and pass through particulate collection devices (28). For this reason, wastes that contain significant amounts of these toxic metals or that have high overall metal content are not considered appropriate for incineration.

Types of Ocean-Incinerable Wastes

Liquid organic wastes are derived from a wide variety of industrial processes and sources. These include activities or uses that: 1) contaminate materials so that they are no longer usable in the process (e. g., spent solvents); 2) produce wastes through purification or recovery of desired products (e. g., distillation wastes resulting from solvent recovery or chemical synthesis); 3) produce wastes through treatment or handling of other wastes (e. g., PCB contamination of solvents used to clean electrical transformers); or 4) result in products that do not meet specifications and therefore must be discarded,

Four major categories of liquid hazardous wastes are generally identified as primary candidates for ocean incineration. These categories, their RCRA classification designations, their primary uses, and their industrial sources are listed in table 2. Special materials or wastes, such as liquid PCBs, are also candidates for ocean incineration. These wastes, which are unique in many respects, are discussed in box B. The four major liquid incinerable waste categories are briefly described below (l).

Waste Oils

These result from the use of lubricants, greases, and other petroleum specialty products. Waste oils are used in a variety of ways because of their high heat content and relative ease of reclamation. Waste oil can be: 1) burned as fuel in boilers and furnaces; 2) used as auxiliary fuel for incineration; 3) re-refined for reuse in its original purpose; or 4) used for dust suppression on roads (a declining practice because of environmental concerns).

A well established and growing market for the reuse of waste oils exists, along with a network for the collection of waste industrial and commercial transportation oils. Collection and reuse of waste automotive oils from individuals is not yet an established practice but is on the rise. As indicated in table 2 and discussed further in chapter 4, waste oils are coming under RCRA regulation as hazardous waste. These regulations have the potential to affect the quantities of such wastes available for incineration.

Nonhalogenated Solvents

Waste solvents are commonly generated as mixtures of solvents, including aromatic hydrocarbons, ketones, alcohols, and esters. Many waste solvents contain large amounts (10 to 50 percent) of water, as well, although this is increasingly avoided through process modifications. The wastes also typically contain significant amounts of suspended solids, including organic and inorganic pigments and heavy metals (lead, chromium, barium, copper, nickel).

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[4]Particulate matter may be composed of metals adsorbed onto dust or soot particles, or actual small metallic fragments. Particulate matter can vary significantly in size, and small particles are captured much less efficiently by air pollution control equipment than are large particles (l).

Table 2.—Major Categories of Ocean-Incinerable Hazardous Waste

Type of waste	RCRA classification	Primary uses	Major sources
waste oils	[a]	Industrial lubricants Transportation oils	Metal and service industries
Nonhalogenated solvents	DOO1, FO03-005	Painting, coating, cleaning operations	Manufacturing
Halogenated solvents	FO01-O02	Cleaning and decreasing agents	Manufacturing Dry cleaning
Other organic liquids.	"K wastes"	Generated in chemical production	Organic chemicals manufacturing

[a]Waste fuel and used oil fuel are coming under RCRA regulation as a result of the 1984 amendments. EPA has proposed listing used oil as a hazardous waste (50 FR 49528,29 November 1965), and has finalized regulations for burning of waste fuel and used oil fuel in *nonindustrial* boilers and furnaces (50 FR 49164,29 November 1965). Burning of waste fuel and used oil fuel in *Industrial* boilers and furnaces is currently exempted from regulation, although EPA plans to regulate this practice under permit standards to be proposed in 1966.

SOURCE: Office of Technology Assessment

Nonhalogenated waste solvents are generally in demand as fuel because of their high heat content (greater than 10,000 Btu/lb). In addition, large quantities of waste solvents are currently cleaned through distillation for recycling or reuse.

Halogenated Solvents

Most halogenated[5] solvents consist of chlorine-containing compounds, with bromine- and fluorine-containing compounds much less common. Waste halogenated solvents are produced in the cleaning and decreasing of metals, machinery, and garments, and hence commonly contain oils, greases, dirt, and other solids. The dry cleaning industry generates substantial quantities of waste perchloroethylene.

Halogenated solvents have a high initial economic value due to the expense of their production and, therefore, are commonly recovered through distillation for reuse. Most halogenated solvents are not in demand as fuel, because they have relatively low heat value (less than 5,000 Btu/lb). In fact, their incineration often requires the use of auxiliary fuel.

[5]Halogens are a group of related chemical elements, which are present in many organic chemical compounds. The group includes fluorine, chlorine, bromine, and iodine.

Other Organic Liquids

A broad range of wastestreams with significant organic content is generated by various industrial processes used to manufacture or purify organic chemicals. Typically each of the wastestreams is homogeneous but may have a unique composition. Many or most wastestreams created in chemical production or purification are specifically listed as hazardous wastes under RCRA, and are referred to as "K" wastes. The wastestreams can contain a very broad spectrum of hazardous constituents. Organic, water, and halogen content, and thus heat value, can also vary significantly.

Several techniques are available or being developed for separating the organic and aqueous fractions of these wastestreams, potentially allowing greater or more economical use of incineration for destroying the organic portion. Although organic wastes mixed with water can be incinerated, the energy requirements (and hence costs) of doing so often increase dramatically as water content increases. However, for a waste whose organic portion has a very high energy content, the presence of water can actually be used to advantage by reducing total heat output to avoid overheating of the incinerator.

QUANTIFYING INCINERABLE WASTE

Waste Inventory

The absolute quantities of incinerable waste may not adequately reflect the degree of *toxicity or hazard* associated with a particular waste type. For example, many industrial wastewaters are composed of extremely dilute aqueous solutions of hazardous chemicals. In contrast, many incinerable wastes are among the most concentrated and toxic of all haz-

[illegible]

In addition to the above disposal and treatment options, a few chemical and biological treatment methods for PCBs have recently received approval.[8] These methods, however, currently can be applied only to wastes with relatively low concentrations (less than 500 ppm) of PCBs (18); they are likely to be particularly useful for cleaning up past disposal sites, which often occurs onsite using mobile units.

Under current regulation, incineration is the only widely applicable technology permitted and available for destroying *liquid* PCB wastes, particularly those with high PCB concentrations. At present, six land-based incineration facilities are approved for incineration of high-level PCBs.[9] EPA permit data from 1984 indicate that these facilities had an annual capacity for some 34,000 metric tons of PCBs, equivalent to roughly 300,000 metric tons of PCB-containing wastes (26). While the great majority of this waste is in liquid form, the cleanup of PCB disposal sites is expected to generate solid PCB wastes as well.

An EPA survey of commercial hazardous waste facilities, including three commercial facilities permitted for PCBs (ENSCO, SCA, and Rollins), indicated that nearly 420,000 metric tons of PCB wastes (almost exclusively liquid) were received in 1984 (8). This data, coupled with reports of several-month backlogs for incineration of PCB liquid wastes (26), indicates a current shortfall in incineration capacity for PCBs. The extent and duration of the shortfall will largely depend on how quickly current electrical equipment is phased out and how much capacity is developed in alternative technologies. Estimates of how long the demand for PCB incineration will substantially exceed capacity typically range from 3 to 10 years, although if additional restrictions are placed on the use of landfills and boilers for disposal of PCB-contaminated material, this period might be lengthened significantly (8,26).

Reasons for Concern Over the Treatment and Disposal of PCBs

The adequacy of the current methods that are used to manage PCB wastes has been the focus of considerable public attention and concern, which is certainly justified in light of the special character of the wastes. Several additional unique features regarding the transport and incineration of PCBs warrant special consideration:[10]

- Because PCBs are no longer commercially produced, they are not routinely transported in commerce, except as waste. This is in contrast to most other liquid incinerable hazardous wastes, which are commonly transported in much greater quantities as *pure* chemicals. The transport of PCBs for incineration thus would not simply represent an incremental increase in risk over that associated with routine commercial transport, as would be the case for most other ocean-incinerable wastes (see ch. 8).
- Of the various candidates for ocean incineration, PCBs are among the most environmentally persistent, and they have the greatest potential to be accumulated by exposed organisms and thereby introduced into the food chain. PCBs are of *intermediate toxicity* relative to other candidates for ocean incineration (7).
- Regulations require that PCBs be incinerated with a higher destruction efficiency than that required for most other wastes. Although this would greatly reduce emissions, verification of this greater destruction efficiency presents a considerable challenge to our current analytical and sampling methods. Indeed, the achievement of a high destruction efficiency during U.S. burns of PCBs at sea could not be demonstrated, because of limits in sampling capability, not because of any demonstrated shortcoming in the incineration process itself (see ch. 11).

Use of Ocean Incineration for PCBs

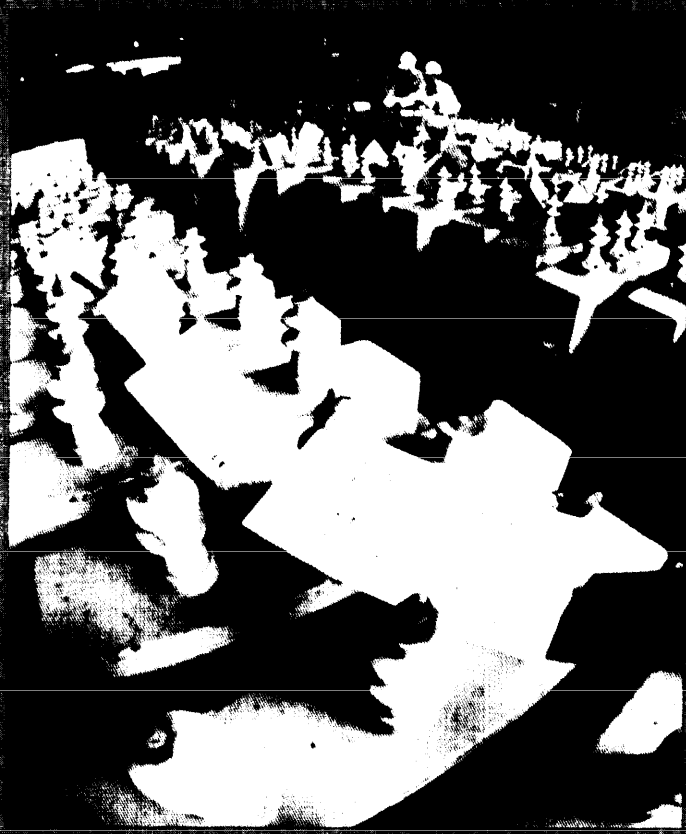
Both international and proposed domestic regulations applicable to ocean incineration give special consideration to PCBs. For PCBs and a few other compounds,[11] international regulations developed under the

[8]Companies that have recently received permits for such [illegible] Chemical [illegible] Contamination Corp., and SunOhio.

[9]Five of these facilities are owned and operated by [illegible] Chemical Services (now owned by Chemical Waste Management) in Illinois, [illegible]. The sixth incinerator is EPA's transportable unit, currently in New Jersey. A seventh incinerator—a transportable unit being built by GA Technologies—also recently received a permit. [illegible] commercial purposes (26).

[10]This discussion is equally applicable to consideration of both land-based and ocean incineration of PCBs.

[11]The other compounds include DDT, polychlorinated terphenyls (PCTs), TCDD (dioxin), and benzene hexachloride. Much of the ensuing discussion in this section also applies to wastes containing these substances.



ardous wastes and, therefore, represent a much larger fraction of the total toxicity attributable to hazardous wastes than their absolute quantity indicates.

Total Hazardous Waste

Given that virtually all ocean-incinerable wastes are classified as hazardous, the starting point for estimating the quantity of such wastes is to examine the various inventories for hazardous waste generation. Unfortunately, no statistically reliable database exists to allow an accurate estimation of the total generation of hazardous wastes. Studies vary tremendously both in the definition of what constitutes hazardous waste and in methodologies for data collection and analysis. In addition, all the studies rely to some extent on sets of simplifying assumptions and models. Although using such assumptions is probably essential for generating a complete national profile, they represent another major and inherent source of variability and uncertainty.

The most prominent (and most often cited) of such studies is the so-called Westat mail survey, which was completed for EPA's Office of Solid Waste in April 1984 (27). The Westat study estimated that 264 million metric tons (equivalent to 71 billion gallons) of hazardous waste were generated in the base year of 1981. This quantity is many times larger than all previous estimates and is generally regarded to be far closer to the actual quantity.

The Westat figure closely agrees with estimates made by the Congressional Budget Office (21) for the base year of 1983, using industrial output models (see below), and by the Office of Technology Assessment (23) for the base year of 1981, using data obtained from a survey of the States. This agreement is somewhat surprising, in view of the fact that the Westat survey was primarily designed to determine numbers of waste generators and treatment, storage, and disposal facilities, rather than waste quantities.

Incinerable Hazardous Waste

Virtually all of the available national data on hazardous waste generation are aggregated by broad industrial categories, rather than by specific waste types. Consequently, the data are not useful in estimating the portion of hazardous waste that is incinerable. Moreover, even the basis for defining a material as a waste is often far from clear. For example, solvents are not always classified as waste if they have the potential to be recovered. And many States do not consider used oils as waste and therefore do not require them to be recorded on manifests, which means estimates of incinerable quantities must be extrapolated from available data on oil use and recovery (1).

Finally, many ill-defined technical, economic, and regulatory limitations bound the universe of incinerable wastes. These and other constraints greatly hinder an accurate measure of how much incinerable hazardous waste is generated annually.

This section discusses two studies that allow an estimation of waste generation by waste type and therefore help to bound estimates of the quantity of incinerable waste. With respect to wastes suitable for ocean incineration, these studies suggest that between 10 million and 21 million metric tons (mmt) of liquid incinerable wastes are generated on an annual basis in the United States.

A recent study by the Congressional Budget Office (CBO) (21) can be used to provide an upper estimate of incinerable waste quantities. This study estimates national generation of hazardous waste in a manner that allows aggregation of the data under any of four classifications: 1) by Standard Industrial Classification (SIC) codes representing major industrial categories (e. g., chemicals and allied products); 2) by waste type (e. g., halogenated liquids); 3) by method of treatment or disposal (e. g., deep-well injection); or 4) by State. Data derived from EPA survey estimates (27) for a base year of 1983 are used to make projections for the year 1990.

The hazardous waste universe as defined by CBO is significantly larger than that currently regulated under RCRA. In particular, the CBO definition includes waste oils, which are only now being brought under RCRA regulation; PCBs, which are regulated under the Toxic Substances Control Act (TSCA); and industrial scrubber sludges, air pollution control dusts, and certain other liquid hazardous wastestreams, which EPA is currently studying for possible future regulation under RCRA.

Several additional features of the CBO study warrant discussion, as they introduce some uncertainty into the resulting estimates of waste generation. Because comprehensive and statistically reliable raw data on which to base waste generation estimates were generally lacking, CBO developed a computer-based model of hazardous waste generation derived from data on industrial output for 70 industrial categories.[12] This approach assumed that specific industries generated particular types of waste at measurable rates. These generation rates were assumed to result from three factors: industrial output (measured by employment directly related to production, on an industry-by-industry basis), process technology, and production efficiency. Estimates of ***future*** waste generation were then derived from projections of growth in industrial employment. CBO found that statistics on employment growth were the only comprehensive and consistent set of industry-specific projections available. Because such statistics only indirectly reflect waste generation, however, a degree of uncertainty was introduced into the resulting estimates (21).

In addition to attempting to account for changes in waste generation resulting from changes in industrial output, CBO also estimated changes due to the application of waste reduction, recycling, and recovery practices. CBO's projected estimates of the levels of ***recycling and recovery*** that could be expected by 1990 were based on information obtained directly through surveys of industrial waste generators and the waste recovery industry. These estimates were then applied to the waste generation estimates, which were derived using the CBO model.

Estimating the future extent of waste ***reduction*** is extremely difficult, given the current lack of data and the absence of an accepted and appropriate means of measuring waste reduction (24). For this reason, CBO's analysis did not consider the full range of approaches that might be used to reduce waste. CBO's estimates, therefore, probably understate the potential for reduction. However, although an enormous amount of waste reduction is possible, many obstacles remain (24).

[12]These 70 industries accounted for about 95 percent of all hazardous waste generated in 1981, according to the Westat survey (27).

Despite these potential shortcomings, the CBO effort represents the ***only*** available source of comprehensive waste generation data that is aggregated on the basis of specific waste types, which is essential for estimating quantities of ***incinerable*** wastes.

Given its limitations, the CBO data maybe best used to derive an upper estimate of incinerable waste generation. Waste generation data are first aggregated by waste type to allow estimation of the quantities of waste generated in those categories that could be managed through incineration. These data are then adjusted downward to account for the levels of recycling, reuse, and recovery that currently take place in each waste category, as estimated by CBO. Finally, separate aggregation of data for liquids versus solids and sludges provides an estimate of quantities of waste that are ocean-incinerable (liquids) and waste that could only be incinerated on land (solids and sludges). Table 3 presents the estimates derived using such a procedure.

The numbers presented in table 3 should be taken as an ***upper bound*** for the following reasons:

- It is unlikely that all of the wastes in each category are physically or economically suitable for incineration.
- Current market factors dictate the use of less expensive disposal practices (e. g., underground injection) even for clearly incinerable wastes.
- Other competing fuel uses, particularly for wastes with high energy content, reduce quantities available for incineration.
- Many incinerable wastes are extensively recovered, reused, or recycled (see column 2 in table 3), and the application of such practices is growing due to clear economic incentives.
- Application of other treatment methods (e.g., chemical detoxification of PCBs) and waste reduction practices to some incinerable wastes is likely to increase in the near future.

Even with these limitations, the CBO data indicate that large quantities of the hazardous waste generated annually could be incinerated, either on land or at sea. This upper estimate indicates that as much as 47 mmt per year, or about one-fifth of all hazardous wastes not currently recovered or recycled, could be incinerated. As much as 21 mmt

Table 3.–Quantities of Incinerable Wastes Generated in the United States, 1983

Type of waste	Quantity generated (mmt)	Current percent RECYC/RECOV[a]	Quantity after RECYC/RECOV[a] (mmt)
Liquids:			
Waste oils	14.25	11%	12.68
Halogenated solvents	3,48	70	1.04
Nonhalogenated solvents	12.13	70	3.64
Other organic liquids	3.44	2	3.37
Pesticides/herbicides	0.026	55	0.012
PUBS	0.001	0	0.001
Total liquids	33.33	380/o	20.74
Sludges and solids:			
Halogenated sludges	0.72	0	0.72
Nonhalogenated sludges	2.24	0	2.24
Dye and paint sludges	4.24	0	4.24
Oily sludges.,.	3.73	5	3.54
Halogenated solids	9.78	0	9.78
Nonhalogenated solids	4.58	0	4.58
Resins, latex, monomer	4.02	65	1.41
Total sludges/solids	29.31	10%	26.51
Total incinerable wastes	***62.64***	***25%***	***47.25***
Total hazardous wastes	**265.60**	***6%***	***249.28***

All quantities are millions of metric tons (mmt).
[a]RECYC/RECOV refers to waste recycling and recovery Practices that affect the quantity of waste needing treatment or disposal. These estimates are derived by CBO from information obtained directly through surveys of industrial waste generators and the waste recovery industry.
NOTE: All other categories listed by CBO are inorganic liquids, sludges, and mixed or solid wastes, with low or no potential for incineration,

SOURCE: Office of Technology Assessment, baaed on U.S. Congress, Congressional Budget Office, *Hazardous Waste Management: Recent Changes and Policy Alternatives* (Washington, DC: U.S. Government Printing Office, 19S5); and unpublished data.

per year are liquids that could be incinerated on land or at sea. In contrast, only an estimated 2.7 mmt—slightly more than 1 percent of all hazardous waste generated in the United States and less than 6 percent of all wastes that could have been incinerated —were incinerated in 1983 (21).

Table 3 indicates that very different quantities of the four major categories of ocean-incinerable waste were generated. CBO estimated that waste oils and nonhalogenated solvents were generated in amounts about four times higher than were halogenated solvents and other organic liquids. After accounting for current levels of recycling, however, waste oils were predominant, and waste halogenated solvents represented the smallest category.

A second study, conducted under contract to OTA, provides a lower bound on the quantities of incinerable hazardous wastes generated nationally on an annual basis. Arthur D. Little, Inc. (1) has developed estimates of ***liquid*** organic hazardous wastes based primarily on data derived from biennial State hazardous waste reports to EPA for the year 1983. These data were aggregated by RCRA hazardous waste codes (40 CFR Part 261, Subpart D) but also include additional wastes considered hazardous under State regulations.

The ADL estimates provide a *lower bound* on the quantities of incinerable hazardous waste, for the following reasons:

- The ADL inventory included only those RCRA categories designating wastes that were essentially 100 percent incinerable, including
  —DOO1 (ignitable wastes),
  —FOO1-FO02 (halogenated solvents), and
  —FO03-FO05 (nonhalogenated solvents).
- The inventory excluded several other categories that contain potentially significant quantities of incinerable wastes, because the incinerable fraction could not be estimated. Excluding these categories undoubtedly means a significant underestimation of total incinerable waste quantities. The categories include:
  —DO02 (corrosive wastes),
  —DO03 (reactive wastes),
  —K wastes (wastes from specific sources),

—P wastes (wastes containing acutely hazardous compounds), and
—U wastes (wastes containing toxic compounds).

- Certain wastes that were managed onsite were specifically excluded from the State reports. These include wastes burned as fuel in industrial boilers and wastes recycled at the facilities where they were generated. Many such wastes are not required to be reported as waste under existing regulations.
- Data that could be used to determine quantities of incinerable liquid wastes generated in 1983 were not available for six States.[13]

ADL's lower bound estimate for the quantity of incinerable liquid wastes in these categories (which exclude waste oils) is 5.8 mmt annually. This can be compared to the somewhat higher CBO estimate of 8.1 mmt (see table 3).

The ADL analysis also included an examination of the use and disposition of waste oils. Of the estimated 2.1 billion gallons annually used in the United States, ADL estimated that about 1 billion gallons are consumed in use, leaving 1.1 billion gallons currently divided between disposal and various forms of reuse (burning as fuel, reclamation, asphalt conditioning, and dust control). This quantity is equivalent to about 4.2 mmt of waste oil annually, which is significantly lower than the 12.7 mmt of waste oil estimated by CBO. The reasons for this large discrepancy are unclear. Both studies, however, estimated that waste oils constitute just over 40 percent of all liquid wastes generated.

In sum, ADL conservatively estimated that a minimum of about 10 mmt of incinerable liquid waste suitable for ocean incineration is generated annually in the United States.

Industries Generating Incinerable Waste

Most incinerable waste is generated by a few major industries. CBO has estimated the amounts of various waste types contributed by industries in each of 12 SIC codes representing major industrial classifications (U.S. Congress, Congressional Budget Office, unpublished data). For each of the four major categories of incinerable liquids, figure 1 shows the industries that together contribute over 90 percent of the wastes. With respect to ***total*** hazardous waste generation, the list includes industries that are major (chemicals and petroleum/coal) and minor (wood preserving and motor freight transportation) contributors (21).

Geographical Distribution of Waste Generation

For both total and ocean-incinerable hazardous wastes, CBO's data allows an estimation of generation rates for 1983 on a State-by-State basis. A regional distribution profile for hazardous waste generation can be developed by adding the estimates for the States comprising each EPA Region. Table 4 presents such a regional profile, and table 5 lists the 10 States in which the most ocean-incinerable hazardous waste is generated. Figure 2 shows the proportion of ocean-incinerable wastes generated by each State in the Nation.

As is apparent from figure 1, the great majority of ocean-incinerable hazardous wastes is generated by the petroleum and chemical industries. Figure 2 indicates, not surprisingly, that at least half is generated along either the Gulf Coast (primarily from petroleum refining) or the Middle Atlantic Coast (primarily from chemical industries).[14] These conclusions are consistent with a comparable analysis performed for OTA using data submitted by the States to EPA in their biennial reports (l).

Thus, a large portion of ocean-incinerable waste would not have to be transported great distances to reach potential ocean incineration port facilities. Moreover, this geographical distribution is consistent with EPA's designation of an ocean incineration site in the Gulf of Mexico, and its proposal for a site located off the Middle Atlantic Coast.

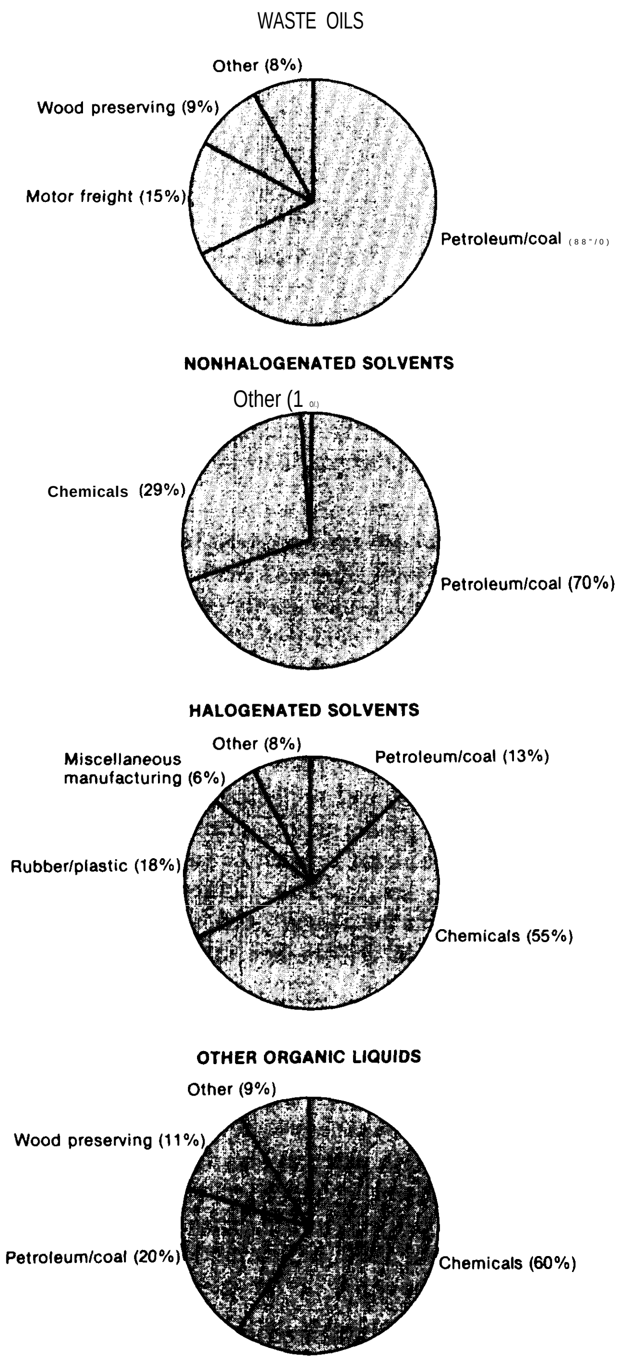
Projections of Future Waste Generation

Projections of future generation of hazardous waste and of liquid organic hazardous waste require the use of assumptions that can drastically affect the resulting estimates. One common approach to

[13] The six States were Arizona, Colorado, Kansas, Oklahoma, Utah, and Wyoming. None of the six are coastal States, and all but two (Kansas and Oklahoma) are expected to be very minor producers of incinerable wastes.

[14] According to the CBO data, Texas alone produces nearly one-quarter of all such liquid wastes (see table 5).

Figure 1.— Major Industries Generating Wastes Suitable for Ocean Incineration



SOURCE: Office of Technology Assessment, based on U.S. Congress, Congressional Budget Office, *Hazardous Waste Management: Recent Changes and Policy Alternatives* (Washington, DC: U.S. Government Printing Office, 1985); and unpublished data.

formulating such projections, therefore, is to design a number of scenarios based on various reasonable sets of assumptions, in the hope of at least bounding the problem. However, estimates derived by such an approach carry a degree of uncertainty that render their use in a policy setting problematic. Given existing deficiencies in the data on which projections must be based, uncertainty is an inherent problem that must be borne in mind when considering any projection of waste generation.

Such projections must also reflect recent changes in the regulatory environment surrounding hazardous waste management. As a result, many additional data gaps and sources of uncertainty are introduced. For example, in adjusting estimates to account for the effect of the land disposal restrictions contained in the 1984 RCRA Amendments (22), assumptions are required about the schedule and extent of their implementation and the anticipated responses of generators and handlers of affected wastes.

The Congressional Budget Office (21) has estimated the quantity of hazardous waste that will be generated and that will require disposal or treatment in 1990. These projections, which are aggregated by waste type, can be compared with the quantities generated in 1983. The projections assume that EPA will meet the land disposal deadlines specified in the 1984 RCRA Amendments, which are scheduled to be largely implemented by that time. [15]

CBO's projection model takes into account two additional variables that could significantly influence the quantities of wastes requiring disposal or treatment in 1990:

1. the extent and effect of waste recovery and recycling activities undertaken by industry; [16] and

[15] CBO indicates that this assumption is perhaps overly optimistic but that any other assumption would be arbitrary. To the extent that the implementation schedule is delayed, use of undesirable land practices will continue, Moreover, many of the specified deadlines are contingent on availability of capacity in alternative treatment technologies.

[16] As indicated previously, CBO has not attempted to account for the full extent of waste *reduction,* because of information on which to base such an analysis is unavailable.

Table 4.–Generation of Ocean-Incinerable and Total Hazardous Wastes, by EPA Region, 1983

EPA region	States	Total hazardous wastes	Percent of total	Ocean-incinerable hazardous wastes	Percent of total
I	CT, MA, ME, NH, RI, VT	11.51 mmt	4.3%	0.78 mmt	2.3%
II	NJ, NY.	22.83	8.6	2.45	
III	DE, MD, PA, VA, WV.	31.82	12.0	2.76	8.3
Iv	Al, FL, GA, KY, MS, NC, SC, TN	39.11	14.7	3.16	9.5
v	IL, IN, MI, MN, OH, WI	62.60	23.6	5.54	16.7
	AR, LA, NM, OK, TX	55.69	21.0	11.75	35.4
VII	IA, KA, MO, NK	11.12	4.2	1.39	4.2
VIII	CO, MT, ND, SD, UT, WY	4.70	1.8	1.18	3.6
Ix	AZ, CA, HI, NV.	18.51	7.0	3.41	10.3
x	AK, ID, OR, WA	7.71	2.9	0.79	2.4
	Totals.	265.60 mmt		33.22 mmt	

SOURCE: **Office of Technology Assessment, baaed** on U.S. Congress, Congressional Budget Office, *Hazardous Waste Management: Recent Changes* ***and Policy Alternatives*** (Washington, DC: U.S. Government Printing Office, **1985);** and unpublished data.

Table 5.—Top 10 States for Generation of Ocean-Incinerable Hazardous Waste, 1983

State	Quantitv (mt/yr)	Percent of all ocean-incinerable hazardous waste
Texas	7,723,175	***23.20/o***
California.	3,199,166	***9.6***
Louisiana.	2,468,357	***7.4***
Pennsylvania.	1,846,652	***5.6***
Illinois	1,782,197	***5.4***
New Jersey	1,674,352	5.0
Ohio	1,304,503	3.9
Oklahoma	1,051,550	3.2
Indiana.	977,969	2.9
Michigan	805,882	*2.4*
		68.6%

SOURCE: Office of **Technology** Assessment, baaed on **U.S. Congress, Congressional** Budget **Office,** ***Hazardous*** *Waste* ***Management:*** *Recent Changes and* ***Policy Alternatives*** **(Washington, DC: U.S. Government Printing Office, 1985); and unpublished data.**

2. changes in baseline waste generation due to expected increases or decreases in the production activities of particular industries, in response to both general and industry-specific economic factors.

Thus, for a given waste category, each of the above factors contributes to any changes predicted to occur between 1983 and 1990.

Expected changes in total hazardous waste generation and in individual waste categories are presented in tables 6 and 7. The summary in table 6 presents CBO's data for the broad categories of incinerable wastes (liquids versus solids and sludges) and nonincinerable wastes, and indicates how both waste recycling/recovery and changes in waste output affect the projected net change in waste quantities. Table 7 presents a more detailed examination of CBO's data aggregated by individual waste type.

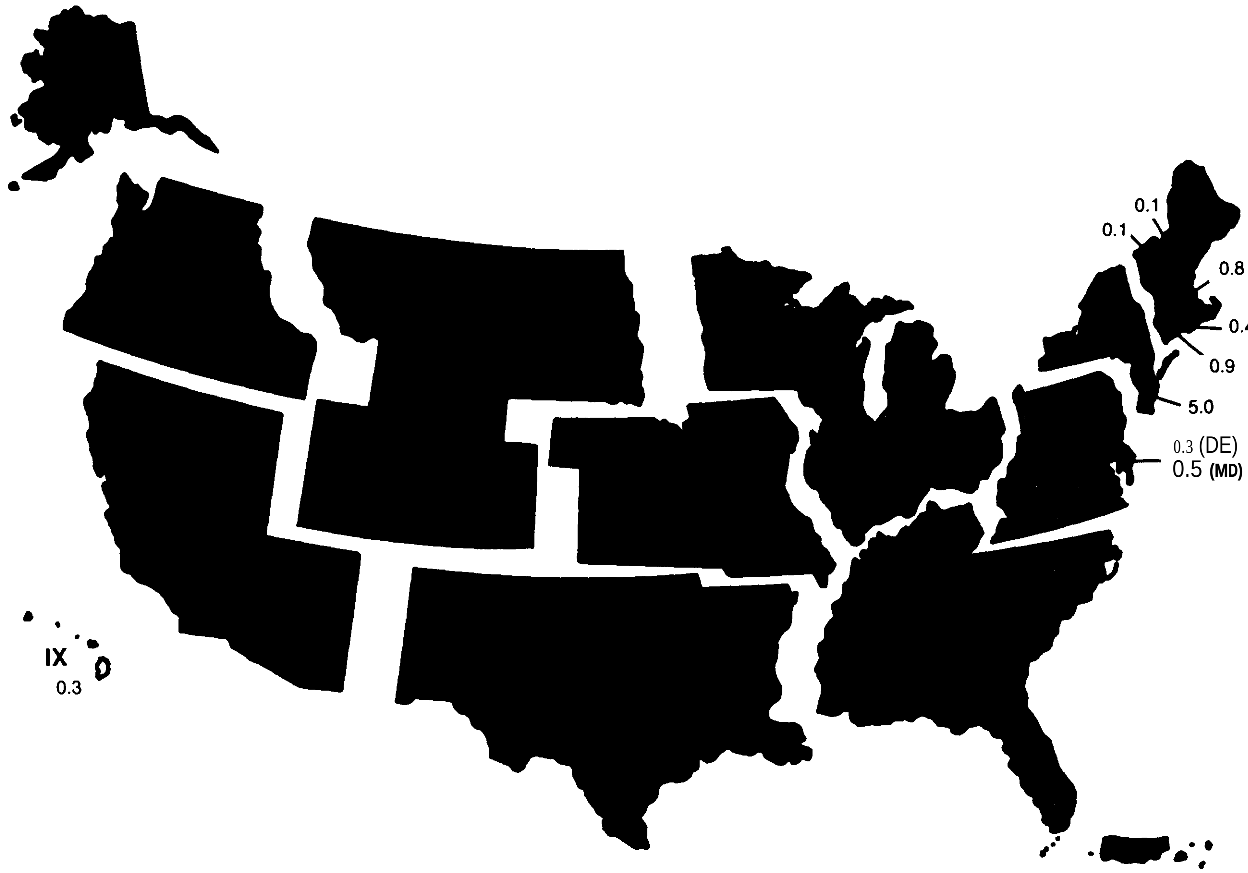
Two major trends are apparent from these data. First, CBO predicts that waste recovery and recycling activities will only modestly decrease the quantities of potentially ***incinerable*** wastes. As shown in column 8 of table 6, the greatest effect of waste recovery and recycling will be on ***nonincinerable wastes.*** These data predict that the decrease in amounts of nonincinerable wastes due to increases in waste recovery and recycling activities will be almost 15 times greater than the decrease in incinerable ***liquids (44*** mmt versus 3 mmt). A few particular waste types, such as metal-containing liquids, will account for a large portion of the decrease in nonincinerable wastes (see table 7).

This trend becomes even more apparent when the actual quantities of wastes expected to be recovered or recycled in 1990 are compared with the figures for 1983 (table 6). For ***nonincinerable wastes,*** almost **45** mmt is projected to be recovered or recycled in 1990, whereas less than 1 mmt is estimated to have been recovered or recycled in 1983. However, the projection for ***incinerable wastes*** is about 20 mmt for 1990, only a modest increase over the 15 mmt recovered or recycled in 1983.[17]

A second trend indicated by these data is that the two factors discussed above—changes in waste generation and the limited application of waste re-

[17] These figures are calculated from the data in table 6 as follows: for 1990, subtract column 5 from column 4; for 1983, subtract column 2 from column 1.

Figure 2.—Percent of Total Ocean.Incinerable Hazardous Wastes Generated by State, 1983



SOURCE: Office of Technology Assessment; based on U.S. Congress, Congressional Budget Office, Hazardous Waste Management: Recent Changes *and Policy Alternatives* (Washington, DC: U.S. Government Printing Office 19S5), and unpublished data.

covery and recycling to incinerable wastes—will both slightly alter the relative amounts of liquids versus solids and sludges generated in 1990. The CBO data (table 6, column 9) predict that the quantities of incinerable solids and sludges will slightly increase between 1983 and 1990 (by about 1 mmt), whereas the quantity of incinerable liquids will slightly decrease in quantity (by about 3 mmt). ***Despite these changes, CBO projects that waste in both categories will continue to be generated in quantities that greatly exceed our current incineration capacity for them.***

Several other sources, including evaluations of future hazardous waste management needs undertaken by a number of States, support the conclusions drawn from this analysis of the CBO data. Two of the sources will be discussed here to lend further support to these conclusions.

The Minnesota Waste Management Board (11) projected that, because of economic growth, Minnesota's generation of wastes in 14 representative categories would increase substantially by the year 2000, even under the State's "high waste reduction alternative. This scenario assumed that wastes would be reduced as much as possible and recycled whenever they had resource recovery potential. Estimates of the extent of waste reduction[18] expected in each category by the year 2000 were

[18]In the Minnesota study, the term waste reduction is broadly applied to include recovery and recycling activities as well as source reduction.

Table 6.-Hazardous Waste Generation in 1983 and 1990: Effect of Recycling and Recovery on Waste Quantities Requiring Treatment or Disposal, Summary of Comparison

	1983			1990			Change in quantity, 1983 to 1990[a]			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Type of waste	Quantity generated (mmt)	Quantity after RECYC/RECOV[b] (mmt)	Percent waste RECYC/RECOV[b]	Quantity generated (mmt)	Quantity after RECYC/RECOV[b] (mmt)	Percent waste RECYC/RECOV[b]	Change in quantity generated (mmt)	Change due to waste RECYC/RECOV[b] (mmt)	Change due to both factors (mmt)	Total percent change[c]
Incinerable wastes:										
Liquids	33.33	20.74	38	33.39	17.80	47	+0.06	−3.00	−2.94	−14.2
Sludges/solids	29.31	26.51	10	32.20	27.61	14	+2.89	−1.79	+1.10	+4.2
Total	62.64	47.25	25	65.59	45.41	31	+2.95	−4.79	−1.84	−3.9
Nonincinerable wastes	202.96	202.03	<1	214.77	169.98	21	+11.81	−43.86	−32.05	−15.9
All hazardous wastes	265.60	249.28	6	280.36	215.39	23	+14.76	−48.65	−33.89	−13.6

[a]Changes occurring between1983 and 1990 are due to two factors: waste recycling/recovery and changes in baseline waste generation. *Both* factors are reflected in this table. For example, examine the entries in the table for incinerable liquids. Comparing the middle columns for 1983 and 1990, there is projected to be a net decrease in incinerable liquid wastes of 2.94 mmt (this is listed in column 9). However, not all of this change is due to waste recycling/recovery activities. Columns 7 and 8 show that the change is due to a slight *increase* in the amount of waste generated (column 7, +0.06 mmt), plus a *decrease* due to waste recycling/recovery (column 8, −3.00 mmt).
Negative (−) signs indicate a decrease in waste quantity. Positive (+) signs indicate an increase in waste quantity.

[b]RECYC/RECOV refers to waste recycling and recovery practices that affect the quantity of waste needing treatment or disposal. These estimates are derived by CBO from information obtained directly through surveys of industrial waste generators and the waste recovery industry.

[c]This percentage is calculated as follows:

$$\text{Total percent change} = \frac{\text{1990 quantity after RECYC/RECOV} - \text{1983 quantity after RECYC/RECOV}}{\text{1983 quantity after RECYC/RECOV}} \times 100$$

SOURCE: Office of Technology Assessment, based on U.S. Congress, Congressional Budget Office, *Hazardous Waste Management: Recent Changes and Policy Alternatives* (Washington, DC: U.S. Government Printing Office, 1985); and unpublished data.

Table 7.—Hazardous Waste Generation in 1983 and 1990: Effect of Recycling and Recovery on Waste Quantities Requiring Treatment or Disposal, Comparison by individual Waste Type[a]

Type of waste	1983 Percent waste RECYC/RECOV	1983 Quantity after RECYC/RECOV (mmt)	1990 Percent waste RECYC/RECOV	1990 Quantity after RECYC/RECOV (mmt)	Percent change in quantity after RECYC/RECOV 1983-1990
Incinerable wastes:					
Liquids:					
Waste oils	11 "/0	12.68	15 "/0	11.84	–6.60/0
Halogenated solvents	70	1.04	80	0.76	–26.9
Nonhalogenated solvents	70	3.64	80	2.37	–34.9
Other organic liquids	2	3.37	25	2.82	– 16.3
Pesticides/herbicides	55	0.012	70	0.008	–33.3
PCBs	0	0.001	0	0.001	0.0
Total incinerable liquids	38	20.74	47	17.80	– 14.2
Sludges and solids:					
Halogenated sludges	0	0.72	0	0.68	–5.6
Nonhalogenated sludges	0	2.24	0	2.48	+ 10.7
Dye and paint sludges	0	4.24	25	3.08	–27.4
Oily sludges	5	3.54	10	3.20	–9.6
Halogenated solids	0	9.78	0	11.56	+ 18.2
Nonhalogenated solids	0	4.58	0	5.23	+ 14.2
Resins, latex, monomer	65	1.41	70	1.38	–2.1
Total incinerable sludges/solids	10	26.51	14	27.61	+4.2
Total incinerabie wastes	25	47.25	31	45.41	*–3.9*
Nonhcinerable wastes:					
Metal liquids	2	19.36	70	5.99	*–69.1*
Cyanide/metal liquids	2	7.24	75	1.82	*–75.0*
Nonmetallic liquids	0	82.26	20	71.93	*– 12.6*
Metal sludge	0	14.50	10	13.63	*–6.0*
Cyanide/metal sludge	0	0.56	15	0.50	*– 10.7*
Nonmetallic sludge	0	28.06	5	26.77	*–4.6*
Contaminated soils	0	5.46	0	5.75	*+5.3*
Metal dusts/shavings	5	7.34	15	6.90	*–6.0*
Nonmetallic dusts	0	21.12	10	19.99	*–5.4*
Explosives	0	0.72	5	0.78	*+8.3*
Miscellaneous wastes	0	15.41	5	15.92	*+3.3*
Total nonincinerable wastes	**<1**	202.03	21	169.98	**– 15.9**
All hazardous wastes	6	249.28	23	**215.39**	**– 13.7**

[a]See footnotes to **table 6 for explanation of** *table*.

SOURCE: Office of Technology Assessment, baaed on U.S. Congress, Congressional Budget Office, *Hazardous Waste Management: Recent Changes and Policy Alternatives* **@Washington, DC: U.S. Government Printing Office, 1966); and unpublished data.**

used to predict the annual quantity of waste that would require treatment or disposal. Table 8 provides these projections for several categories.

The data from the Minnesota analysis support the conclusions drawn by the CBO study:

- a net increase will occur in future quantities of incinerable wastes, including liquids, even after accounting for waste reduction;
- the application of waste reduction, recycling, and recovery practices will be greater for nonincinerable wastes than for incinerable wastes; and
- substantial quantities of ***both*** organic solids/sludges and liquids will require treatment into the foreseeable future.

The New Jersey Hazardous Waste Facilities Siting Plan (5) estimated the effect of waste reduction on the quantities of various types of hazardous wastes that are sent offsite for treatment or disposal. Baseline quantities were projected for 1988, and then adjusted to account for the anticipated extent of waste reduction. Table 8 shows the data for several major categories of incinerable and nonincinerable hazardous waste.

Table 8.—Two State Estimates of Future Hazardous Waste Generation and Extent of Waste Reduction (all quantities in thousands of metric tons)

	Minnesota		
	Baseline projection for 2000	Downward adjustment for waste reduction	Net change in quantity over 1982
Incinerable:			
Solvents/organic liquids	33		+7
Oils and greases	75	–22	–3
Organic sludges/bottoms	8	0	+2
Nonincinerable:			
Inorganic liquids/sludges	42	–28	–17
All hazardous wastes	**212**	**–66**	**–13**

	New Jersey		
	Baseline projection for 1988	Downward adjustment for waste reduction	Net change over average quantity for 1981 to 1983
incinerable:			
Organic liquids	95	0	+35
Solvents	34	–4	+2
Oils	69	–3	+5
Nonincinerable:			
Inorganic liquids	122	-21	–6
All offsite **waste**	**418**	–30	+41

SOURCES: Minnesota Waste Management Board, 19S4; and Environmental Resources **Mangement,** Inc., New Jersey Hazardous ***Waste Facilities Plan,*** prepared for New Jersey Waste **Facilities** Siting Commission (Trenton, NJ: March 1985).

This analysis of data for New Jersey wastes sent ***offsite*** also supports the same general conclusions as the CBO study: most waste reduction will be applied to nonincinerable wastes, and even after accounting for such activity, large and increasing quantities of incinerable (as well as nonincinerable) waste will require treatment.

Onsite Versus Offsite Management of Hazardous Wastes

Another important distinction to be made in discussing quantities of waste likely to require treatment or disposal is whether waste management activities occur within the facility at which wastes were generated (onsite), or at a separate, typically commercial, facility ***(offsite).*** Each of these waste management strategies poses its own special advantages, requirements, and risks. For example, offsite management introduces the added burdens of transportation and recordkeeping, although inspection and enforcement are generally accomplished more easily at offsite facilities.

Whether a waste generator decides to manage its wastes onsite or offsite largely depends on the size of the generator. Some generators can realize economies of scale sufficient to make investment in onsite facilities attractive, and others generate wastes in quantities too large to make offsite transport practicable; small generators typically find it more cost-effective to ship wastes to commercial facilities for treatment or disposal. The onsite versus offsite distinction is especially relevant to ocean incineration, which is by definition offsite.

The majority of all hazardous waste is disposed or treated onsite, although available estimates vary over a considerable range. The Westat survey (27) and the CBO study (21) estimated that less than 5 percent of all hazardous waste was managed or disposed of offsite. Interestingly, a number of State or regional analyses found that a somewhat larger proportion was managed offsite. For example, Minnesota's data indicated that at least 15 percent of its hazardous waste was managed offsite (1 1). Two New Jersey studies reached disparate estimates: One study (5) suggested that only a small percentage of all waste was sent offsite;[19] the other (28) in-

[19] If wastewater were excluded from this calculation, an estimated 25 percent would be sent offsite.

dicated that 26 percent of New Jersey's hazardous waste was sent for offsite disposal or treatment. A recent study of hazardous waste management in New England found that the region's waste was divided almost evenly between onsite and offsite management (14).

Unfortunately, none of these data concerning on/offsite distribution was aggregated by waste type, which precludes a separate evaluation for those wastes with potential for incineration at sea. However, other data suggest that most liquid organic hazardous wastes are managed onsite. The Westat survey (27) found that about 0.9 mmt of liquid organic hazardous wastes was incinerated in land-based facilities in 1981, and that 98 percent of this activity took place onsite. And the EPA market analysis (26) found that at least 90 percent of current incineration of liquid wastes took place in private onsite facilities.

Current land-based incineration of all forms of hazardous waste follows a similar distribution: In 1983, 210 to 250 onsite hazardous waste incinerators managed an estimated 2.4 mmt, and about 30 offsite incinerators managed about 0.4 mmt (2, 10, 19,21).

Considerable uncertainty surrounds projections of onsite versus offsite waste management and, more specifically, incineration. It is not known whether, and to what extent, waste generators facing restrictions on land disposal options will choose (or will be able) to develop additional onsite capacity or will instead send more waste to commercial facilities. Clearly, the future market for ocean incineration will be influenced to a large degree by such decisions.

Several studies have estimated potential shifts in onsite versus offsite treatment and disposal. CBO (21) projected that the quantity of all hazardous waste sent offsite will roughly double from 1983 to 1990. The magnitude of this shift depends on whether the 1984 RCRA restrictions on land disposal are implemented according to schedule; if delays occur, the increase in offsite treatment would be more gradual. CBO indicated that the trend toward offsite treatment would be particularly strong for wastes that can be incinerated or chemically treated, and that existing capacity in these technologies could be surpassed easily.

A considerably less dramatic shift is forecast by the majority of respondents to an EPA survey of selected commercial hazardous waste management firms (8). According to these respondents, changes in the level of offsite treatment and disposal would be limited at most to a ' 'small (perhaps 4 to 6 percent), short-term pulse, " primarily because of facility closures under new RCRA restrictions .[20] Furthermore, they expect that offsite shipment of wastes will eventually decline as waste reduction practices are implemented. A minority of respondents to the survey, however, predicted a larger increase of 10 percent or more in response to RCRA restrictions and also argued that "generators have already exhausted most of their options to reduce waste volumes.

Capacity of and Demand for Offsite Treatment Facilities

The shifting of waste from onsite to offsite treatment is only one of several factors that contribute to the *overall* demand for commercial treatment facilities. Other factors include:

- an increase in actual waste generation, because of economic growth;
- changes that result from new regulatory controls, such as more stringent regulations that govern the burning of hazardous waste in boilers, restrictions on the use of land disposal practices, or increased implementation and enforcement of effluent guidelines;
- closure of existing facilities that are unable to comply with new regulations *or* unwilling to incur the additional costs of compliance; and
- cleanup of uncontrolled hazardous waste disposal Sites.

Several countervailing factors also may affect overall demand:

- an increase in the capacity of existing facilities, whether they are private or commercial;

[20]Some observers have questioned the reliability of information obtained from existing commercial hazardous waste firms, arguing that these firms have a strong self-interest in downplaying ***any future need*** for additional facilities. Aside from this issue, whether such a survey is representative of the industry is questionable; indeed, EPA cautions readers that ' 'no statements can be made about the ***entire*** commercial hazardous waste management industry from this small sample" (8).

- increasing waste or volume reduction by generators that are seeking to minimize the amounts of waste requiring offsite treatment; and
- increasing use of mobile treatment facilities that are designed to treat wastes at the site of generation.

Each of these factors is very difficult or impossible to assess in any quantitative manner. Nevertheless, several States attempted to account for these factors in studies of future demand for offsite treatment capacity.[21] Virtually all of these studies projected a substantial growth in the demand for offsite capacity into the foreseeable future, although estimates of the magnitude of growth varied considerably.

The studies also support the corollary that a shortfall between offsite treatment capacity and demand is expected if substantial growth in existing capacity does not occur.[22] Given this, capacity could be increased by: 1) developing new facilities, or 2) expanding capacity at existing facilities. Although both of these avenues are being pursued, progress has been very slow:

- The firms surveyed in the EPA study (8) have generally abandoned plans to develop *new* facilities, because of local public opposition and because operating permits cannot be obtained without a minimum delay of several years.
- Some of these firms indicated plans to expand their incineration and other treatment capacity at existing facilities; however, they again cited significant delays in obtaining permits as a major obstacle, and argued that "stretching out existing capacity can only go so far. Eventually, new sites must be brought on-line."
- CBO (21) indicated that—at the current rate of permitting for hazardous waste treatment, storage, and diposal facilities—7 to 10 years would be needed to issue the final permits that these facilities must have to continue operating.[23]
- In a survey of private (onsite) treatment facilities in New Jersey, facility owners expressed very little interest in expanding capacity and/or commercializing their operations to help meet the projected shortfall in treatment capacity (5).

This discussion illustrates that the magnitude of the expected shortfall in offsite hazardous waste treatment capacity is exceedingly difficult, if not impossible, to estimate. Despite this, the demand for such capacity clearly will increase. The next section addresses these same issues with a focus on projecting the use of and demand for ***incineration*** capacity.

Future Use of and Demand for Incineration Capacity

Numerous studies have indicated that the actual use of and demand for ***incineration*** technologies to manage hazardous waste will increase significantly (1,5,8,16,17,21,28). This trend is a reflection of the ability of these technologies to destroy the organic portion of wastes and significantly reduce waste volume:

> Thermal destruction systems have become recognized over the past decade as an increasingly desirable alternative to the more traditional methods of disposing of hazardous wastes in landfills, lagoons, and injection wells (17).

As one example of these studies, CBO (21) projected that incineration of hazardous wastes would triple or quadruple (from 2.7 mmt in 1983 to 8.2 to 11.6 mmt in 1990). The higher estimate assumed that no waste recycling and recovery beyond current levels would be undertaken; the lower estimate assumed that waste recycling and recovery efforts would achieve the level reflected in tables 6 and 7. CBO also indicated that the increased use of incineration would be the single largest change in the use of all hazardous waste management technol-

[21] These include efforts undertaken in Missouri, New Jersey (5), New York, North Carolina, and Pennsylvania. References and more detailed analyses of these studies are presented in ref. 24.

[22] For example, the Minnesota Waste Management Board (11) concluded that "there is not sufficient capacity at the present time to treat all of the hazardous wastes amenable to treatment in the United States. As increasing emphasis is put on treatment as an alternative to disposal of hazardous wastes, there may be an overall shortage in treatment capacity. Another observer indicated that "little growth of available commercial incineration capacity may be expected over the short term. A three- to five-year delay is possible before significant new capacity could be available" (17).

[23] Section 213 of the 1984 RCRA Amendments requires that all incineration facilities receive final permits within 5 years of enactment, and all other treatment facilities within 8 years.

ogies, and that incineration would increasingly be used to manage organic liquid, sludge, and solid wastes.

The EPA survey of commercial hazardous waste management firms (8) also revealed that increased quantities of waste were being directed toward incineration, a phenomenon clearly attributed by the respondents to the first effects of the new RCRA restrictions on land disposal. At least for the portion of the commercial market represented by this survey, waste quantities received for incineration were increasing at a faster rate than incineration capacity .24

The survey respondents argued that future increases in demand for incineration capacity would be primarily for organic solids and sludges, and that liquid capacity was sufficient and would probably remain so. Unfortunately, no data were presented that indicated the relative quantities of the different physical forms of incinerable waste that were received .25

Attempts To Project the Future Market for Ocean Incineration

As part of EPA's "Assessment of Incineration as a Treatment Method for Liquid Organic Hazardous Waste, Booz-Allen & Hamilton, Inc., conducted an analysis of the near-future ***commercial market*** for incinerable liquid wastes. The study (26) was intended to directly quantify the potential size of the ocean incineration market. The analysis, however, was complicated by a set of constraints beyond those confronting the studies cited above. Because the study focused on the ***commercial sec-***tor of the incineration industry, assumptions had to be made regarding, for example, the relative proportion of incinerable wastes to be managed onsite versus offsite, and the contribution of commercial land-based incineration and other facilities to the overall market picture for incinerable liquid wastes,

The result was a study that has been criticized as being statistically unreliable and as failing to account sufficiently for the use of technologies other than incineration. EPA indicated that the study did not (and was not intended to) fulfill the requirement for EPA to conduct a formal needs assessment for ocean incineration, as specified under the Marine Protection, Research, and Sanctuaries Act. Rather, the study was intended to serve as a general indicator of the size of the potential shortfall in commercial liquid incineration capacity, in support of EPA's contention that there maybe a need for ocean incineration. (For a fuller discussion of uncertainties inherent in the market study, see refs. 4,15,26,29).

Despite its flaws, EPA's incineration market assessment was generally consistent with virtually all other available studies. The major finding predicted a significant and growing shortfall in incineration capacity as a result of: 1) increases in the quantities of wastes generated and available for incineration, and 2) very slow development of capacity in incineration and other technologies for managing such wastes.

EPA's market analysis (26) projected the potential demand for ocean incineration based on a quantification of the shortfall in future commercial incineration capacity for ***liquid*** wastes.[26] A range of projections was derived under scenarios involving implementation of one or more of the land disposal restrictions embodied in the 1984 RCRA Amendments. Assuming full implementation of all of the RCRA restrictions, a range was estimated for the quantity of excess liquid waste that would be shifted away from land disposal. Managing the quantity of wastes at the midpoint of that range would require 33 incinerator ships with a capacity of 50,000 mt per ship per year (or 82 additional land-based incinerators at 20,000 mt per year).

This midpoint projection would represent an increased demand for ***commercial liquid waste incineration capacity*** of 1.65 mmt annually. [27] As would be expected, CBO's estimate of the increase

[24] These firms reported that the amount of wastes received for incineration increased by 48 percent from 1983 to 1984, while their incineration capacity increased by only 18 percent.

[25] As discussed Previously, incinerable liquids are often in demand because of their fuel value, Receiving these wastes from generators is clearly attractive to commercial incineration firms, because burning them reduces the need to use auxiliary fuel when burning solids and sludges that have a lower energy content. Thus, separate discussions of liquid capacity and solids and sludge capacity do not appear to be particularly meaningful.

[26] This finding has been contested b, land-based incineration companies (see ch. 2).

[27] The range in projected increased demand was considerable, from 0.75 to 2.55 mmt annually. This corresponded to a range of 15 to 51 incinerator vessels, or 38 to 128 land-based incinerators. The extent of this range is one indicator of the degree of uncertainty accompanying such projections.

in *total* ***use of incineration*** (i. e., both commercial and private facilities burning liquids, sludges, and solids) was higher, by a factor of 3 to 5.[28] Thus, despite major differences in methodology and somewhat different estimates, these two studies were roughly consistent; both supported the conclusion that, in the near future, there will be increased demand for capacity to manage liquid incinerable wastes.

EPA's market analysis cast its results in terms of a specific demand for liquid incineration capacity. A more neutral statement of the result, however, is that the capacity to ***manage incinerable wastes is*** expected to fall short of demand. This shortfall could (and likely will) be addressed in a number of ways. For example, development of ocean incineration capacity ***or*** expansion of land-based incineration capacity ***or*** both could help to meet this demand. Alternatively, it could be partially met by other means now used for a portion of these wastes—including chemical treatment, recycling and recovery, and use as fuel in industrial boilers and furnaces. Finally, the quantities of waste requiring treatment could be decreased through increased application of waste reduction practices. Accurately estimating the future use of ***any*** of these technologies is highly complex, if not impossible.

Thus, a future need for ocean incineration (or land-based incineration, or any other hazardous waste management technology) may never be unequivocally demonstrated or quantified from an ***analytical*** standpoint. Nevertheless, given the generally acknowledged shortfall in our present and future capacity to manage incinerable wastes, the development of several options will likely be necessary.

Other Factors Affecting Future Waste Generation and Management

The two most important variables with respect to hazardous waste generation and management in the near future appear to be: 1) the extent and schedule of implementation of the new (1984) RCRA authority (which bans certain wastes from land disposal) as well as future changes in the RCRA definition and classification of hazardous wastes (e. g., for waste oils); and 2) the extent of application of new and emerging waste reduction, reuse, and recovery technologies and strategies.

In addition to banning some wastes from land disposal, two other changes in RCRA resulting from the 1984 amendments will increase the quantities of hazardous waste by bringing heretofore unregulated wastestreams or generators under RCRA authority:

1. Exemptions for hazardous wastes or used oils burned as fuel are being removed, and new regulations governing their blending, burning, and recycling for reuse are mandated. CBO (21) estimated that, in 1983, significantly more hazardous waste was burned in RCRA-exempt industrial boilers and furnaces than was incinerated (9.5 mmt versus 2.7 mmt). EPA estimated that 3.4 to 5.4 mmt of hazardous waste and used oils are burned annually in industrial boilers (50 FR 1684, Jan. 11, 1985). See chapter 4 for a detailed discussion of this topic.
2. The waste level below which generators are exempted from regulation has been reduced from 1,000 to 100 kilograms per month, thereby greatly increasing the number of regulated small generators; EPA (50 FR 31285, Aug. 1, 1985) estimated that the number of RCRA-regulated generators would increase from the current 14,000 to a total of 175,000, but that these small generators account for only about 760,000 metric tons per year of hazardous waste (much less than 1 percent of the national total).

Conversely, new RCRA requirements for implementing waste reduction and detoxification programs and increasing industrial efforts aimed toward waste reduction, recycling, and recovery would be likely to moderate or reduce future hazardous waste generation. The full impact of such measures depends on a variety of regulatory, institutional, and economic variables and is therefore exceedingly difficult to predict.

[28] CBO's range was 8.2 to 11.6 mmt annually. After accounting for current use of incineration at 2.7 mmt annually, this would represent an increase of 5.5 to 8.9 mmt annually. Thus, compared to the EPA value of 1.65 mmt, CBO's values were three to five times higher.

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