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Management of Hazardous Waste in the United States

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ABSTRACT

The National Hazardous Waste Survey was used to examine hazardous waste management methods. The methods used to manage industrial hazardous waste were grouped into 16 technological categories. For each category, the types of waste managed, the industry sectors generating the waste and the geographical distribution of management technologies are reported. Since many wastes are managed using a sequence of technologies, the interdependence of waste management methods was also examined. The survey reveals that wastemater treatment processes handle the vast majority of hazardous waste treatment (approximately 730 million tons in 1986). Incineration and waste reuse as fuel were used to manage on the order of 4 million tons in 1986. Geographical distribution of management facilities closely mirrors geographical distributions of waste generation since 96% of wastes examined in this survey are managed on site. However, the geographical distribution of particular management technologies is far from uniform. For example, underground injection is most commonly used in EPA Region VI while waste piles are most commonly used in Region V.

INTRODUCTION

Millions of tons of hazardous wastes are generated each year in the United States. Prior to the late 1980s, a detailed accounting of the management patterns for these waste streams was unavailable, however, with the data collection provisions enacted under the Superfund reauthorization and the Resource Conservation and Recovery Act (RCRA), the legal authority to collect such data was put in place. Now there are several databases which provide partial pictures of hazardous waste generation and management. Several of these databases are described in this special issue of Hazardous Waste and Hazardous Materials. This work will focus on the National Hazardous Waste Survey (1,2). This survey is the most detailed source of information available on hazardous waste management methods. It has two basic components, a generator survey focusing on waste characterization and a survey of treatment, storage, disposal and recycling facilities (TSDR), focusing on waste treatment and disposal. Both parts of the survey will be used in this paper to determine patterns of usage for hazardous waste management technologies. In this work we will begin by grouping management technologies into broad categories. Then, for each technology category, we will examine the types of wastes that are

managed in the units, the industry sectors that generated the wastes and where the units are located.

METHODS

National Hazardous Waste Survey

The source for the data used in this paper is the National Hazardous Waste Survey (HWS) assembled by the Research Triangle Institute (RTI) under a contract from EPA. This database consists of two data sets:

- National Survey of Hazardous Waste Treatment, Storage, Disposal and Recycling Facilities (TSDR).
- National Survey of Hazardous Waste Generators (GENSUR)

The TSDR survey contains detailed information on some 2600 TSDR facilities that were in use in 1986. The data collected include general facility information such as onsite treatment practices, storage and recycling practices and facility schematics, information on different treatment or recovery facilities, information on land disposal, and on storage tank systems. The GENSUR data base contains information on some 40,000 waste streams which fall under the provisions of the Resource Conservation and Recovery Act (RCRA). This data set provides detailed information on quantities such as waste stream flow rate, fraction managed onsite, metal loading, halogen loading, a description of the source of the waste, an ultimate analysis, and a listing of the treatment or disposal processes used for the waste. A more complete description of the database is available elsewhere (1,2).

RESULTS

The waste management technologies that will be examined in this work are listed in Table I, together with the quantity of waste managed using the technology during the calendar year 1986. The National Hazardous Waste Survey was used to determine, for each of the sixteen management technologies, specified in the survey:

a) types of waste managed
b) industry sectors generating the wastes
c) geographical distribution of the management technologies

The results are reported in Figures 1(a-c) through 16(a-c). In each case, Figure a) reports the types of waste managed, Figure b) reports the industry sectors generating the waste and Figure c) gives the geographical distribution of the management methods. Table II lists the dominant industrial sector generating the waste for each management method.

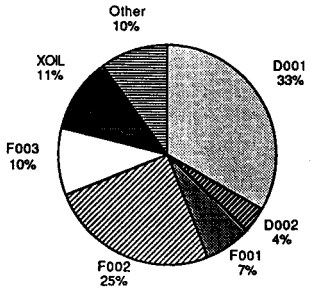
DISCUSSION

Before beginning a detailed discussion of waste management technologies, it is useful to have an overview of waste management practices. Figure 17 provides that overview. It reports the mass of waste managed in each of thirteen different types of technologies (storage and other treatment are not included here, and surface impoundment and disposal impoundment are integrated as one method). It shows the management patterns and approximate amounts of industrial waste streams, regulated under RCRA, which are processed through various treatment and disposal routes. The flow rates in Figure 17 are totals for approximately 40,000 industrial waste streams generated from all U.S. industry regulated under RCRA in 1986, the last year for

Table I.

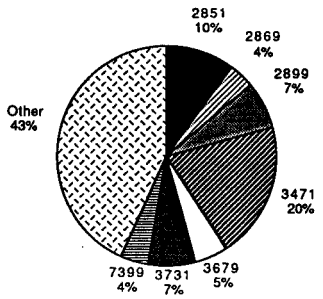
Management Method	Quantity Managed in 1986[a] (Million tons)	Number of Facilities
Metal recovery	1.44	330
Solvent recovery	1.18	1470
Other recycling	0.96	243
Fuel blending	0.75	177
Reuse as fuel	1.44	295
Incineration	1.09	197
Solidification	0.77	122
Land treatment	0.38	58
Wastewater treatment	732	4399
Disposal impoundment[b]	4.61	70
Surface impoundment[c]	232	298
Landfill	3.17	118
Waste pile	0.68	71
Underground injection	28.7	63
Storage (RCRA permitted)	189	1785
Other treatment	1.98	128

[a]Quantities reported were obtained using the TSDR section of the survey. Total waste generated in 1986 was 747 million tons; note that some wastes were managed in multiple treatment technologies and that wastes can be sent to and removed from storage.
[b]Surface impoundments used for disposing of hazardous waste.
[c]Includes waste entering surface impoundments for disposal, treatment and storage.



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
F001	Spent Halogenated Solvents Used In Degreasing
F002	Spent Halogenated Solvents
F003	Spent Nonhalogenated Solvents
XOIL	Waste Oil

Figure 1a. Total Waste Managed In Solvent Recovery By Waste Type



Industry Code	Industry Description
2851	Paints and Allied Products
2869	Industrial Organic Chemicals, nec
2899	Chemical Preparations, nec
3471	Plating and Polishing
3679	Electronic Components, nec
3731	Ship Building and Repairing
7399	Business Services, nec

Figure 1b. Total Waste Managed In Solvent Recovery By Industry Code

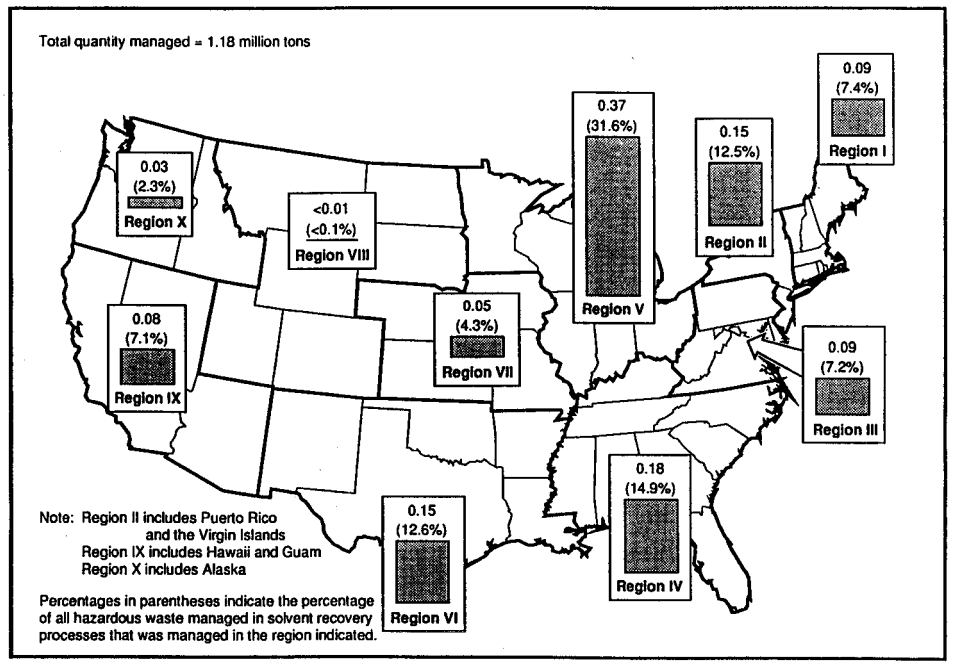
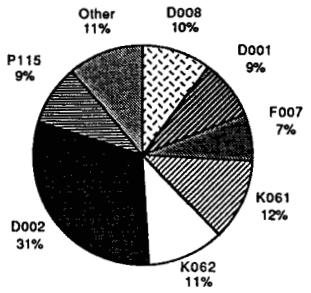
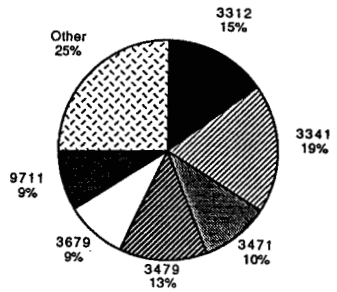


Figure 1c. Quantity of Hazardous Waste Managed In Solvent Recovery Processes per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D002	Corrosive Waste
D008	Lead
D011	Silver
F007	Spent Cyanide Plating Bath Solutions From Electroplating Operations
K061	Emission Control Dust/ Sludge From Primary Production of Steel in Electric Furnaces
K062	Spent Pickle Liquor From Steel Finishing Operations That Produce Iron or Steel
P115	Thallium (I) Sulfate

Figure 2a. Total Waste Managed In Metal Recovery By Waste Type



Industry Code	Industry Description
3312	Blast Furnaces and Steel Mills
3341	Secondary Nonferrous Metals
3471	Plating and Polishing
3479	Metal Coating and Allied Services
3679	Electronic Components, nec
9711	National Security

Figure 2b. Total Waste Managed In Metal Recovery By Industry Code

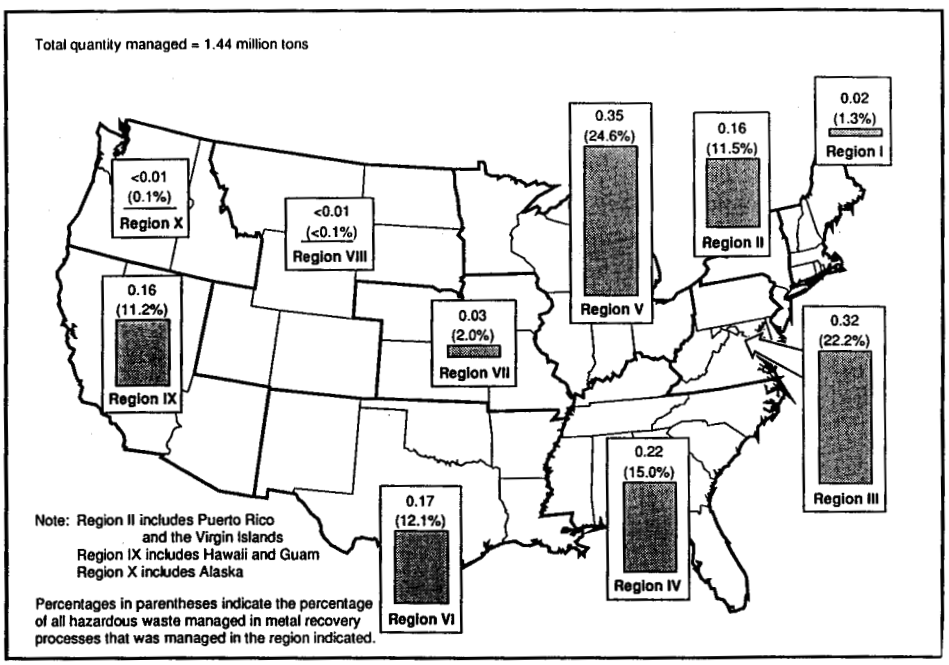
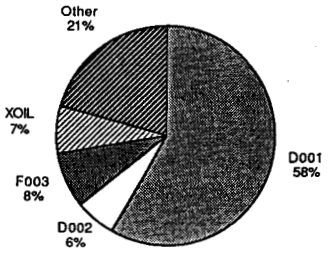
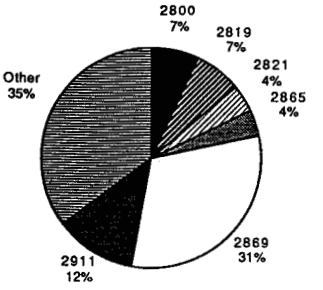


Figure 2c. Quantity of Hazardous Waste Managed In Metal Recovery Processes per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
F003	Spent Nonhalogenated Solvents
XOIL	Waste Oil

Figure 3a. Total Waste Managed In Reusing As Fuel By Waste Type



Industry Code	Industry Description
2800	General Chemical Manufacturing
2819	Industrial Inorganic Chemicals, nec
2821	Plastic Materials and Resins
2865	Cyclic Crudes and Intermediates
2869	Industrial Organic Chemicals, nec
2911	Petroleum Refining

Figure 3b. Total Waste Managed In Reusing As Fuel By Industry Code

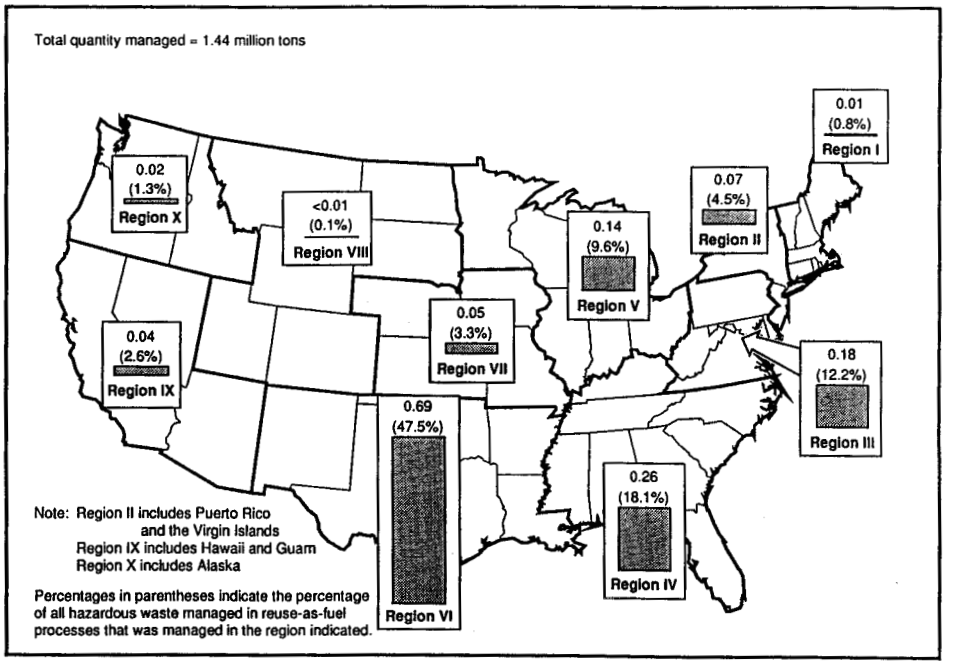
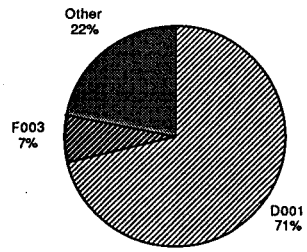
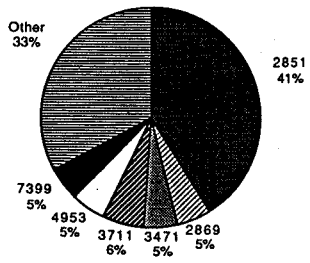


Figure 3c. Quantity of Hazardous Waste Managed In Reuse-as-Fuel Processes per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D001	Ignitable Waste
F003	Spent Nonhalogenated Solvents

Figure 4a. Total Waste Managed In Fuel Blending By Waste Type



Industry Code	Industry Description
2851	Paints and Allied Products
2869	Industrial Organic Chemicals, nec
3471	Plating and Polishing
3711	Motor Vehicles and Car Bodies
4953	Refuse Systems
7399	Business Services, nec

Figure 4b. Total Waste Managed In Fuel Blending By Industry Code

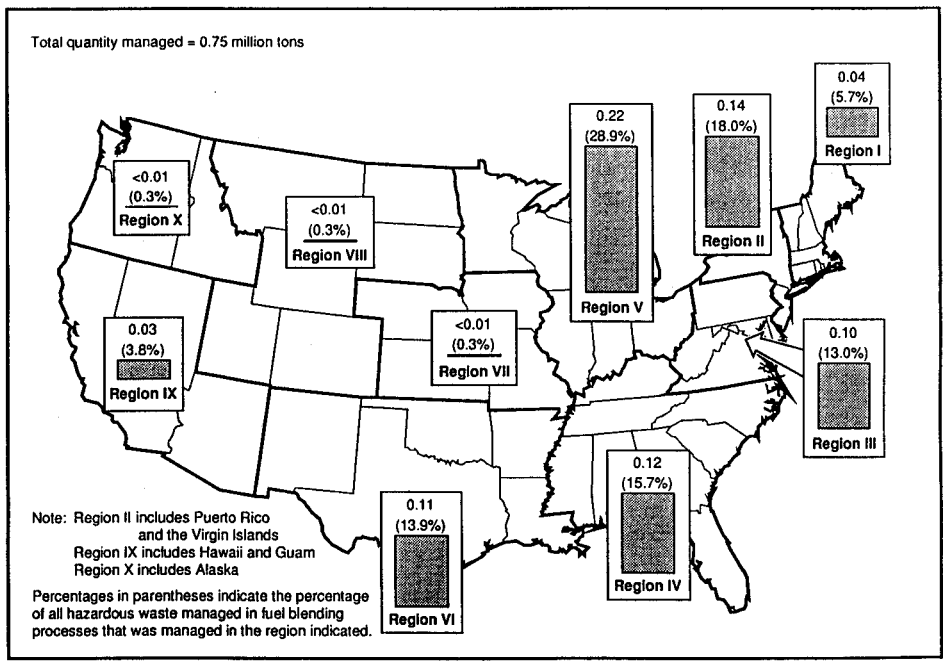
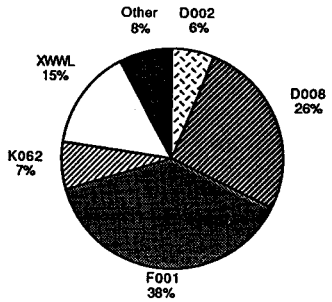
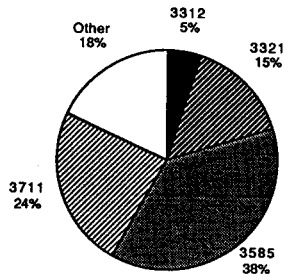


Figure 4c. Quantity of Hazardous Waste Managed in Fuel Blending Processes per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D002	Corrosive Waste
D008	Lead
F001	Spent Halogenated Solvents Used In Degreasing
K062	Spent Pickle Liquor From Steel Finishing Operations That Produce Iron or Steel
XWWL	Hazardous Wastewater Treatment Liquid

Figure 5a. Total Waste Managed In Other Recycling By Waste Type



Industry Code	Industry Description
3312	Blast Furnaces and Steel Mills
3321	Gray Iron Foundries
3585	Refrigeration and Heating Equipment
3711	Motor Vehicles and Car Bodies

Figure 5b. Total Waste Managed In Other Recycling By Industry Code

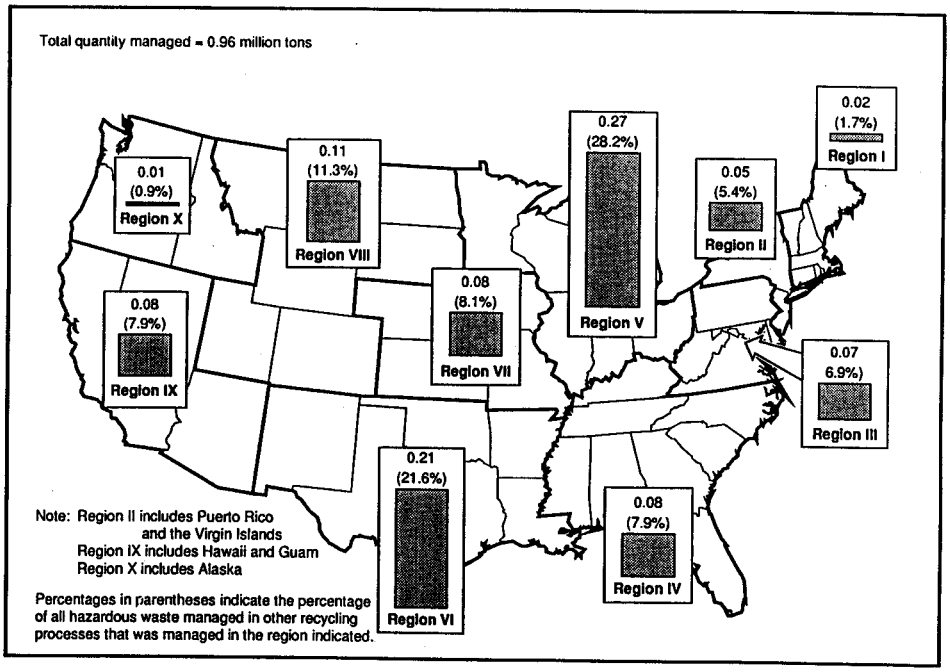
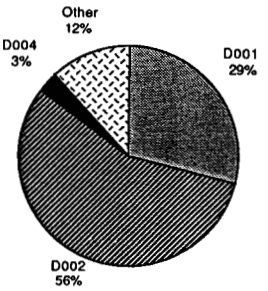
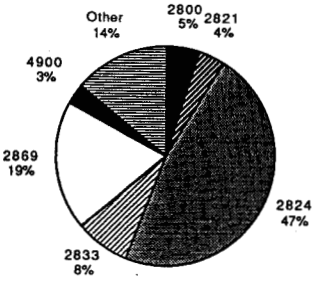


Figure 5c. Quantity of Hazardous Waste Managed In Other Recycling Processes per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
D004	Arsenic

Figure 6a. Total Waste Managed In Incineration By Waste Type



Industry Code	Industry Description
2800	General Chemical Manufacturing
2821	Plastics Materials.and Resins
2824	Organic fibers, noncellulosic
2833	Medicinals and botanicals
2869	Industrial Organic Chemicals, nec
4900	Electrical, Gas, and Sanitary Services

Figure 6b. Total Waste Managed In Incineration By Industry Code

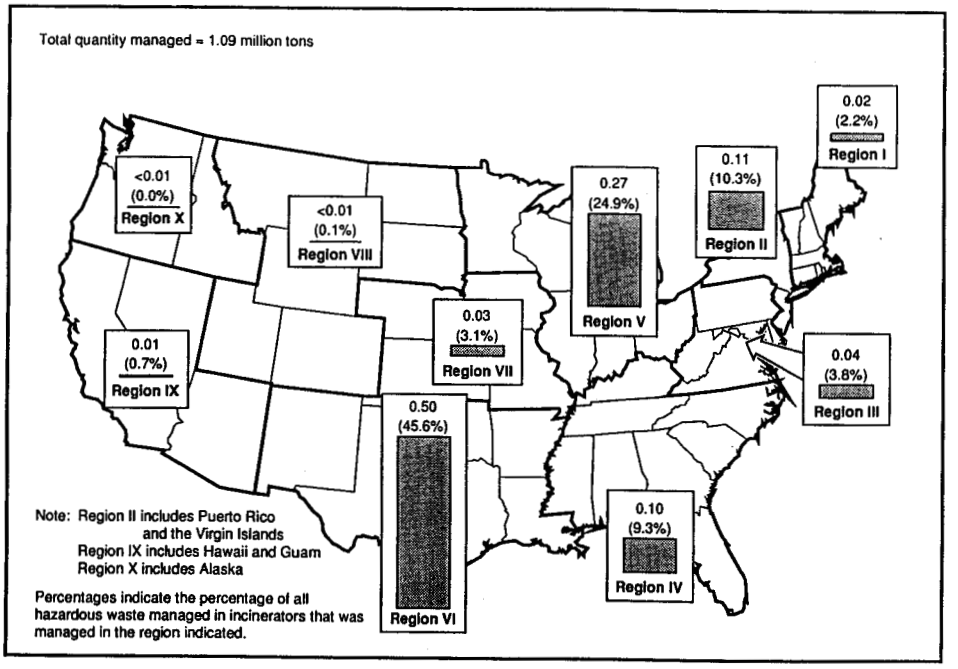
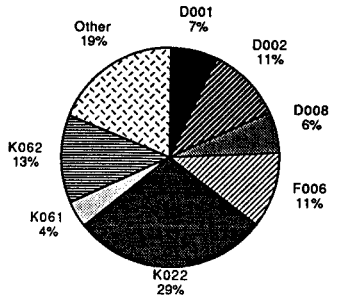
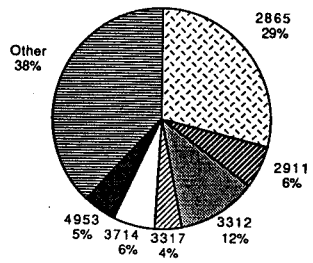


Figure 6c. Quantity of Hazardous Waste Managed in Incinerators per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
D008	Lead
F006	Wastewater Treatment Sludges From Certain Electroplating Operations
K022	Distillation Bottom Tars From the Production of Phenol/Acetone From Cumene
K061	Emission Control Dust/ Sludge From Primary Production of Steel in Electric Furnaces
K062	Spent Pickle Liquor From Steel Finishing Operations That Produce Iron or Steel

Figure 7a. Total Waste Managed In Solidification By Waste Type



Industry Code	Industry Description
2865	Cyclic Crudes and Intermediates
2911	Petroleum Refining
3312	Blast Furnaces and Steel Mills
3317	Steel Pipe and Tubes
3714	Motor Vehicle Parts and Accessories
4953	Refuse Systems

Figure 7b. Total Waste Managed In Solidification By Industry Code

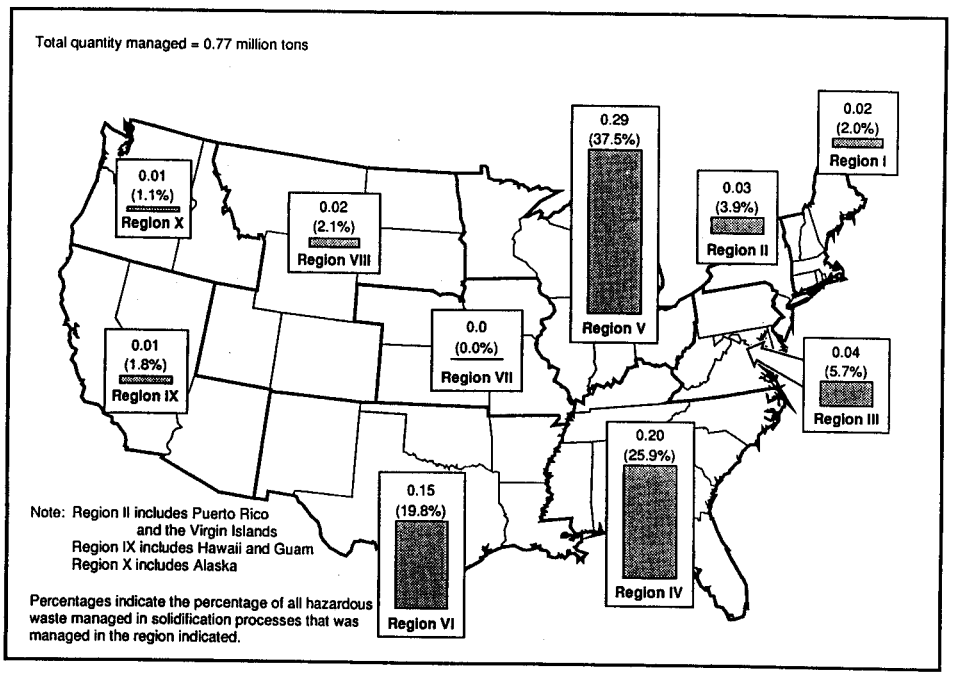
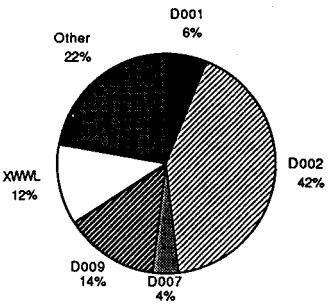
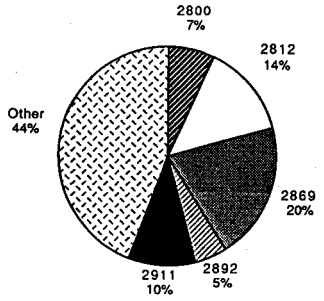


Figure 7c. Quantity of Hazardous Waste Managed in Solidification Processes per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
D007	Chromium
D009	Mercury
XWWL	Hazardous Wastewater Treatment Liquid

Figure 8a. Total Waste Managed In Wastewater Treatment By Waste Type



Industry Code	Industry Description
2800	General Chemical Manufacturing
2812	Alkalies and Chlorine
2869	Industrial Organic Chemicals, nec
2892	Explosives
2911	Petroleum Refining

Figure 8b. Total Waste Managed In Wastewater Treatment By Industry Code

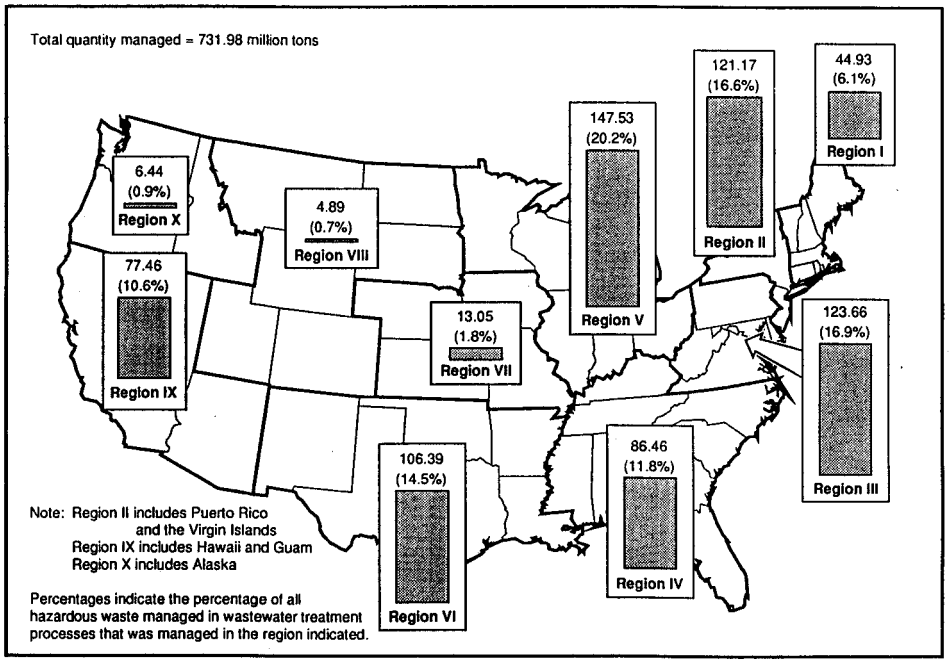
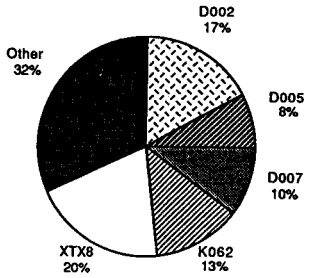
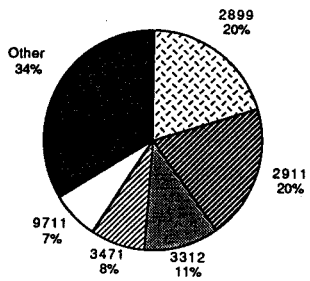


Figure 8c. Quantity of Hazardous Waste Managed In Wastewater Treatment Processes per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D002	Corrosive Waste
D005	Barium
D007	Chromium
K062	Spent Pickle Liquor From Steel Finishing Operations That Produce Iron or Steel
XTX8	

Figure 9a. Total Waste Managed In Other Treatments By Waste Type



Industry Code	Industry Description
2899	Chemical Preparations, nec
2911	Petroleum Refining
3312	Blast Furnaces and Steel Mills
3471	Plating and Polishing
9711	National Security

Figure 9b. Total Waste Managed In Other Treatments By Industry Code

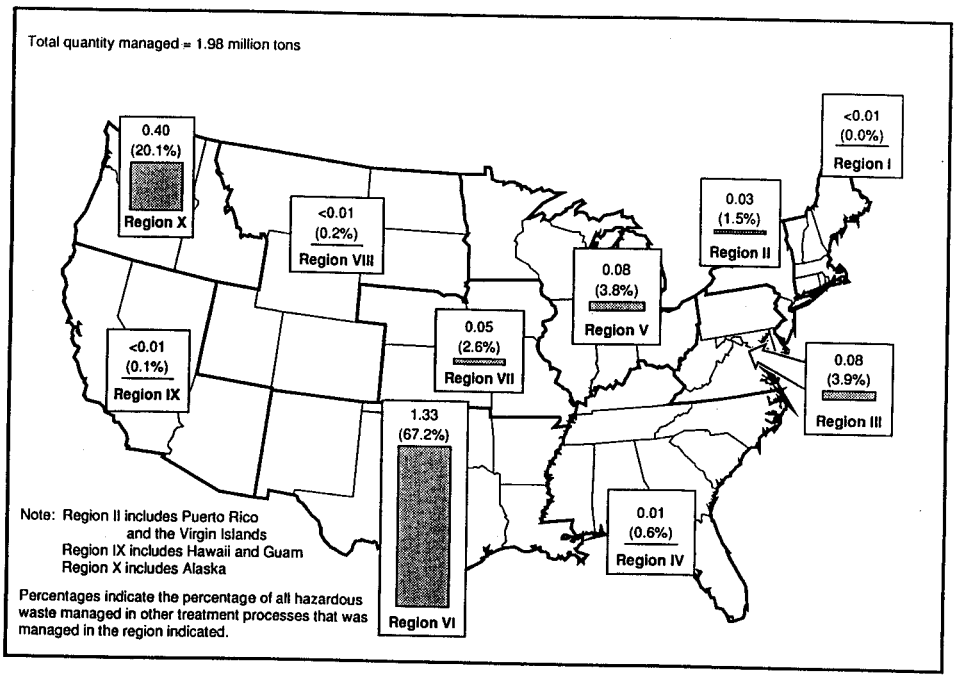


Figure 9c. Quantity of Hazardous Waste Managed In Other Treatment Processes per EPA Region In 1986 (In million tons)

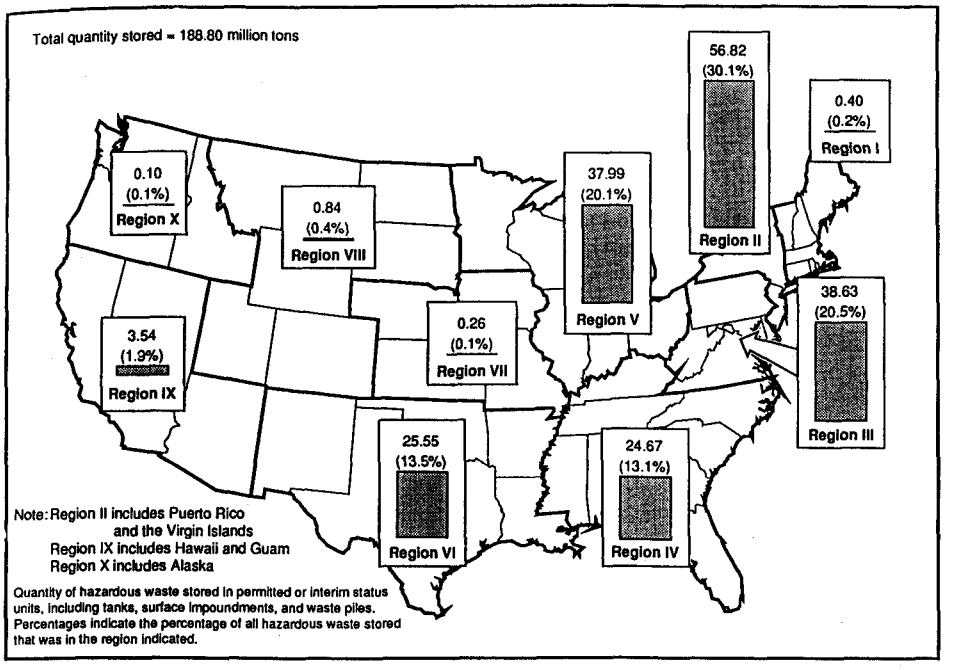
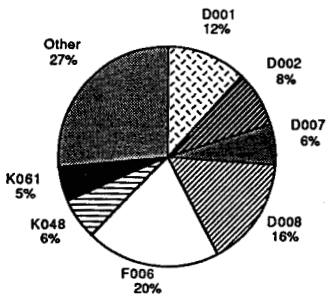


Figure 10 Quantity of Hazardous Waste Stored per EPA Region in 1986 (in million tons)

which complete data are available. This figure provides useful information about the relative amounts of the wastes managed by different techniques. For example, it indicates that a small fraction of wastes flows through recycling loops. The total mass involved in solvent, metal and other recycling is about 5 million tons per year (mt/yr). The largest single stream in terms of total mass flow, approximately 730 mt/yr (more than 90% of the total waste mass flow), is hazardous wastewater. Most of this stream is water, hence the mass of the chemically hazardous component of this stream is on the order of the components being recycled. A third set of waste streams, about 4 mt/yr, is sent to various thermal treatment technologies which include direct incineration, fuel blending and reuse as fuel. Although incineration destroys less than 1% of the hazardous waste mass currently generated, these incinerated wastes generally contain moderate to high concentrations of regulated substances.

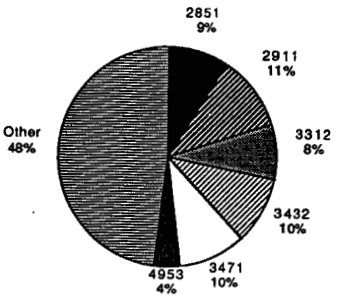
Figure 17 also reveals the interdependencies of many waste management technologies. For example, roughly 1.0 million tons of waste were incinerated in 1986. Scrubbers in the air pollution control equipment of these incinerators generated 40 million tons of wastewaters that are legally defined as hazardous and which must be treated as hazardous wastewaters. So, the waste flow diagram shows 1 million tons of waste entering the incineration step and 40 million tons leaving the incineration step. Other interdependent management technologies include wastewater treatment and land treatment (biological sludges from hazardous wastewater treatment plants are sent to solidification and hazardous waste landfills); material from waste piles and surface impoundments are sometimes sent to landfills and solvent and metal recovery operations generate hazardous wastewaters. From Figure 17 it is clear that waste management frequently involves multiple technologies.

Given that waste management is frequently a multistep process, examination of usage patterns for individual technologies must be done with care and the data must not be over interpreted. Returning to Figures 1a-16a, which focus the wastes managed in individual treatment technologies we see that many of the wastes have been described by characteristic, i.e. ignitable (D001), corrosive (D002) or reactive (D003). These results must be used with caution. The



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
D007	Chromium
D008	Lead
F006	Wastewater Treatment Sludges From Certain Electroplating Operations
K048	Dissolved Air Floatation (DAF) Float From Petroleum Refining Industry
K061	Emission Control Dust/ Sludge From Primary Production of Steel in Electric Furnaces\\\

Figure 11a. Total Waste Managed In Landfill By Waste Type



Industry Code	Industry Description
2851	Paints and Allied Products
2911	Petroleum Refining
3312	Blast Furnaces and Steel Mills
3432	Plumbing Fittings and Brass Goods
3471	Plating and Polishing
4953	Refuse Systems

Figure 11b. Total Waste Managed In Landfill By Industry Code

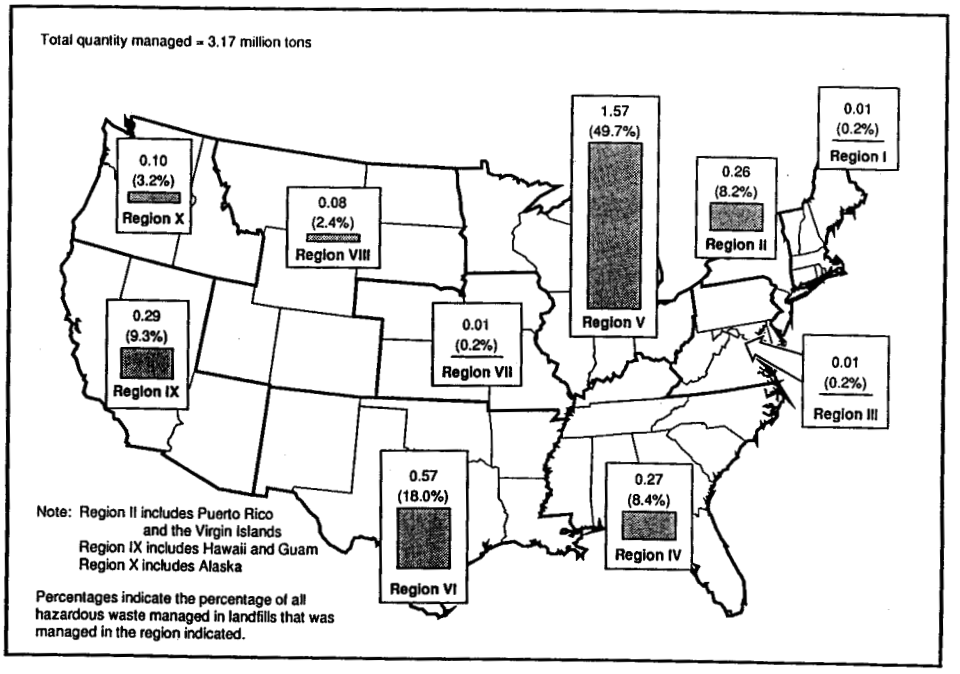
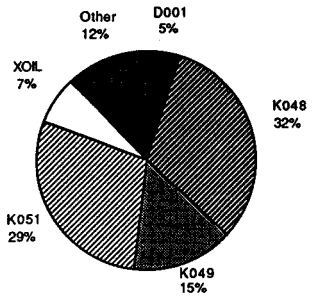
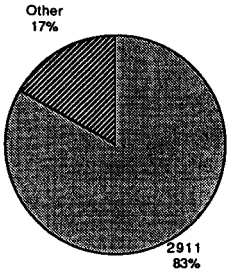


Figure 11c. Quantity of Hazardous Waste Managed In Landfills per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D001	Ignitable Waste
K048	Dissolved Air Floatation (DAF) Float From the Petroleum Refining Industry
K049	Slop Oil Emulsion Solids From the Petroleum Refining Industry
K051	API Separator Sludge From the Petroleum Refining Industry
XOIL	Waste Oil

Figure 12a. Total Waste Managed In Land Treatment By Waste Type



Industry Code	Industry Description
2911	Petroleum Refining

Figure 12b. Total Waste Managed In Land Treatment By Industry Code

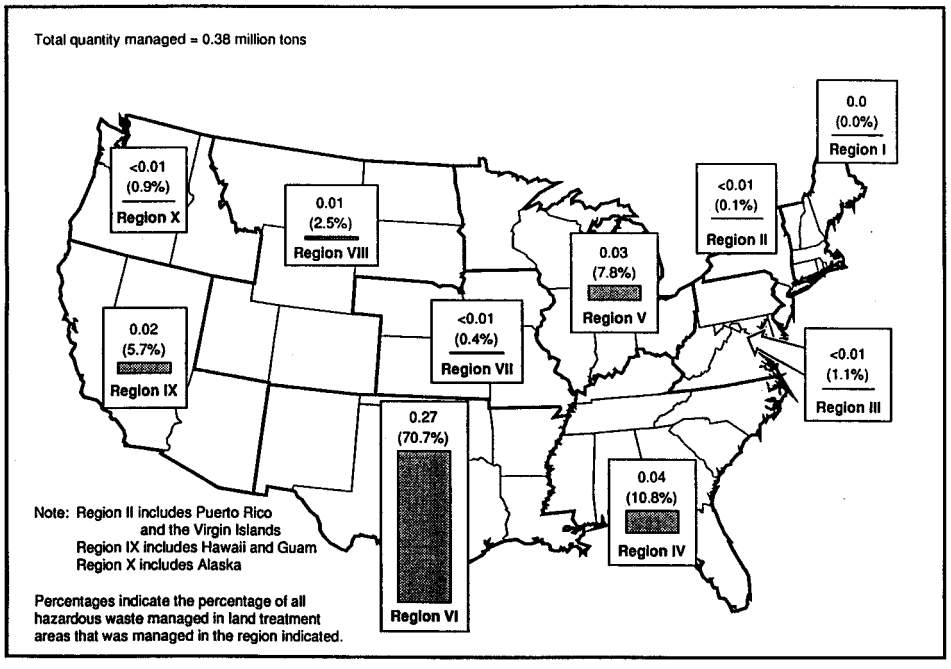
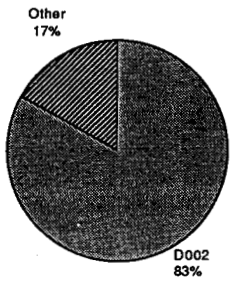
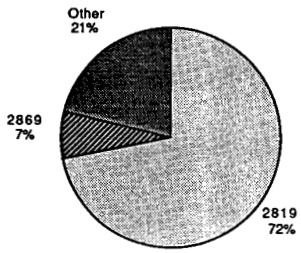


Figure 12c. Quantity of Hazardous Waste Managed In Land Treatment Areas per EPA Region In 1986 (in million tons)



Waste Code	Waste Description
D002	Corrosive Waste

Figure13a. Total Waste Managed In Disposal Impoundment By Waste Type



Industry Code	Industry Description
2819	Industrial Inorganic Chemicals, nec
2869	Industrial Organic Chemicals, nec

Figure 13b. Total Waste Managed In Disposal Impoundment By Industry Code

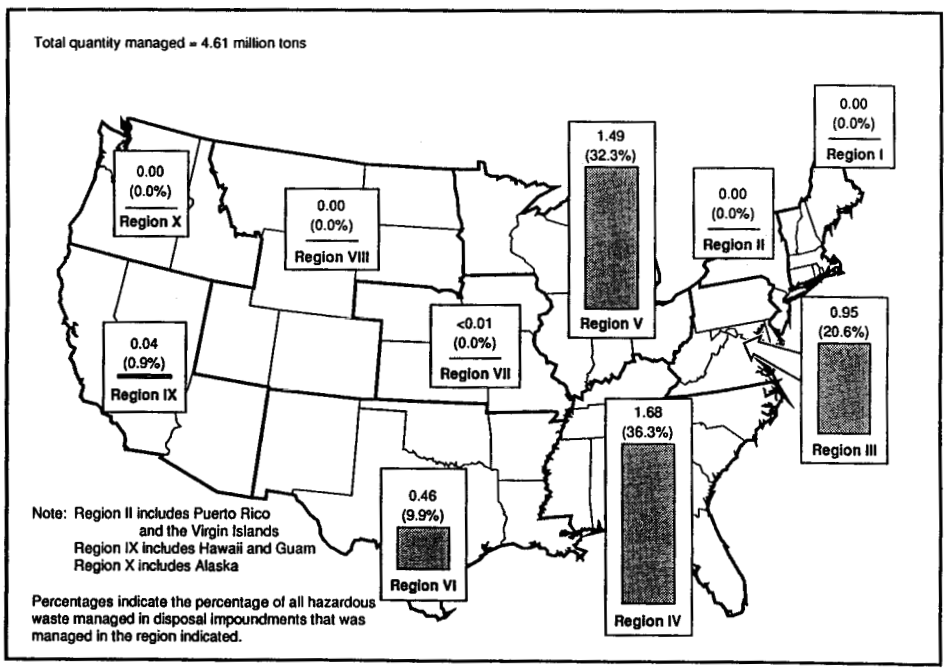
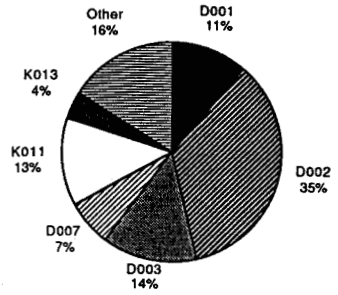
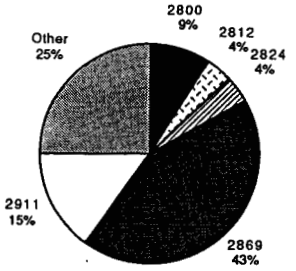


Figure 13c. Quantity of Hazardous Waste Managed In Disposal Impoundments per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D001	Ignitable Waste
D002	Corrosive Waste
D003	Reactive Waste
D007	Chromium
K011	Bottom Stream From the Wastewater Stripper in Production of Acrylonitrile
K013	Bottom Stream From the Acrylonitrile Column in Production of Acrylonitrile

Figure 14a. Total Waste Managed In Injection Wells By Waste Type



Industry Code	Industry Description
2800	General Chemical Manufacturing
2812	Alkalies and Chlorines
2824	Organic Fibers, noncellulosic
2869	Industrial Organic Chemicals, nec
2911	Petroleum Refining

Figure 14b. Total Waste Managed In Injection Wells By Industry Code

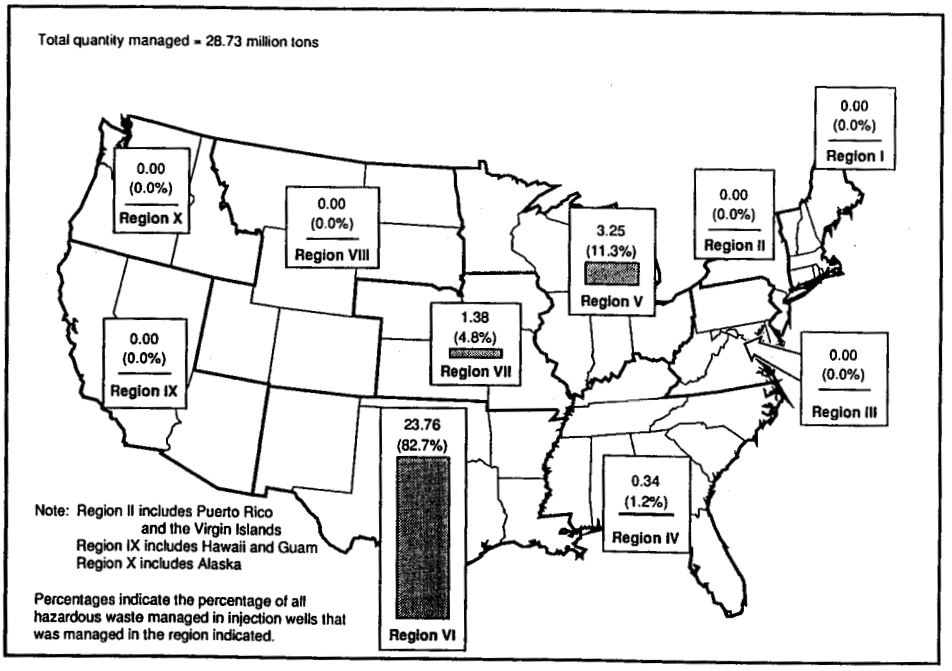
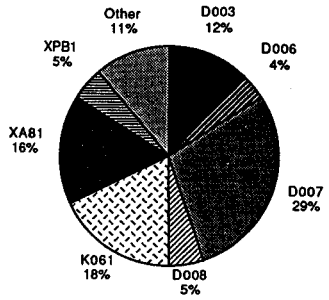
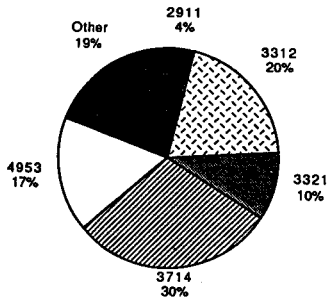


Figure 14c. Quantity of Hazardous Waste Managed In Injection Wells per EPA Region In 1986 (In million tons)



Waste Code	Waste Description
D003	Reactive Waste
D006	Cadmium
D007	Chromium
D008	Lead
K061	Emission Control Dust/ Sludge From Primary Production of Steel in Electric Furnaces
XA81	
XPB1	Waste Which Has Concentration of Polychlorinated Biphenyls Less Than 50 Parts Per Million

Figure 15a. Total Waste Managed In Waste Pile By Waste Type



Industry Code	Industry Description
2911	Petroleum Refining
3312	Blast Furnaces and Steel Mills
3321	Gray Iron Foundries
3714	Motor Vehicle Parts and Accessories
4953	Refuse Systems

Figure 15b. Total Waste Managed In Waste Pile By Industry Code

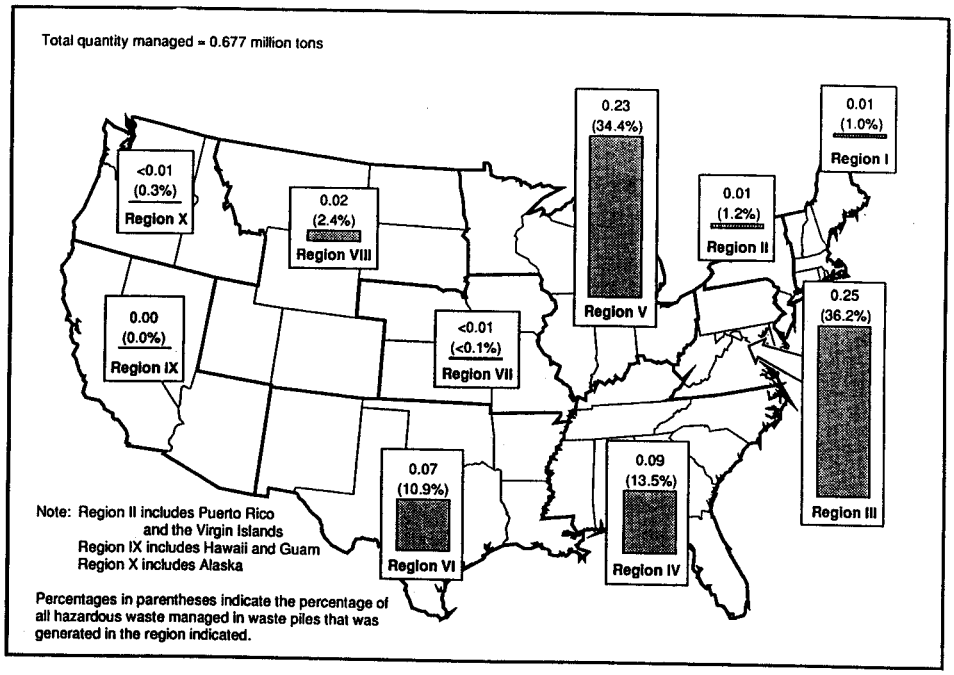
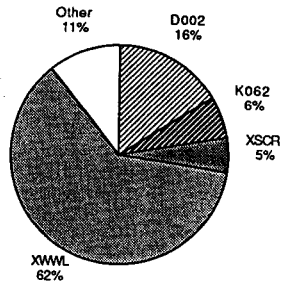
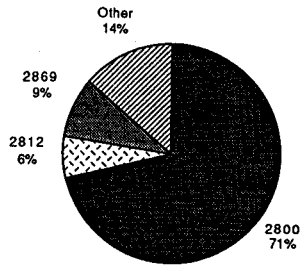


Figure 15c. Quantity of Hazardous Waste Managed In Waste Piles per EPA Region in 1986 (in million tons)



Waste Code	Waste Description
D002	Corrosive Waste
K062	Spent Pickle Liquor From Steel Finishing Operations of Plants That Produce Iron or Steel
XSCR	Hazardous incinerator, boiler, or furnace scrubber water
XWWL	Hazardous wastewater treatment liquid

Figure 16a. Total Waste Managed In Surface Impoundment By Waste Type



Industry Code	Industry Description
2800	General Chemical Manufacturing
2812	Alkalies and Chlorine
2869	Industrial Organic Chemicals, nec

Figure 16b. Total Waste Managed In Surface Impoundment By Industry Code

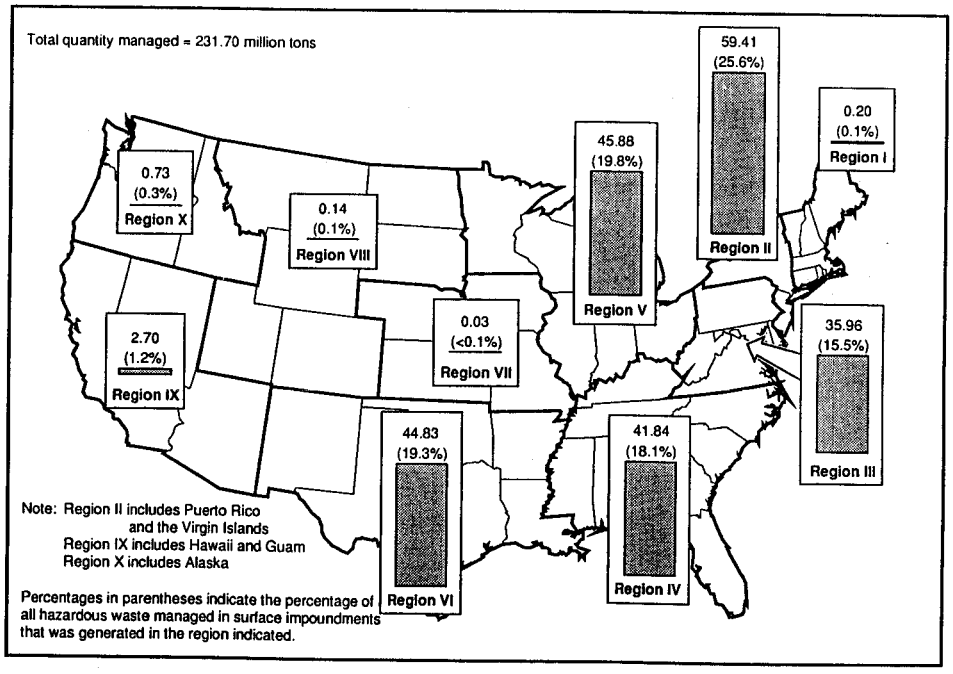


Figure 16c. Quantity of Hazardous Waste Managed In Surface Impoundments per EPA Region in 1986 (in million tons)

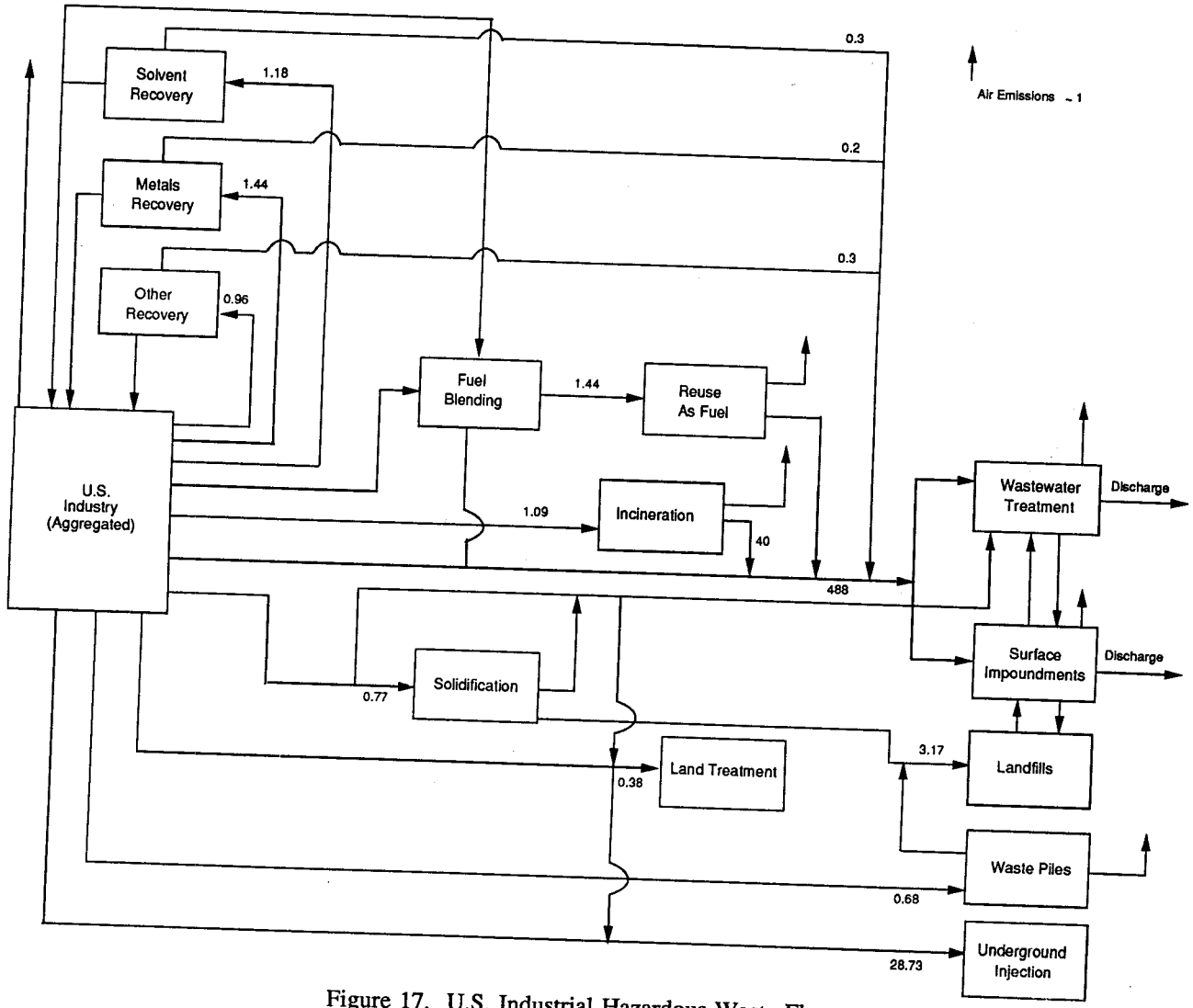


Figure 17. U.S. Industrial Hazardous Waste Flows

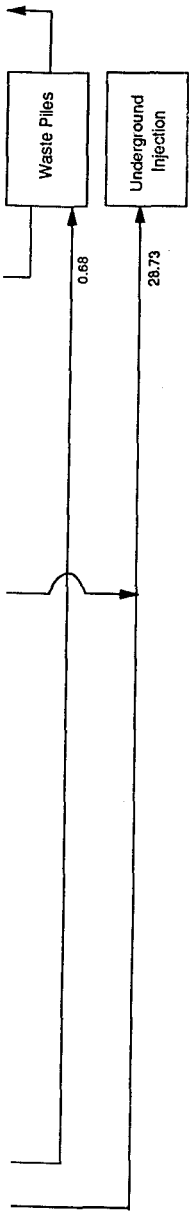


Figure 17. U.S. Industrial Hazardous Waste Flows

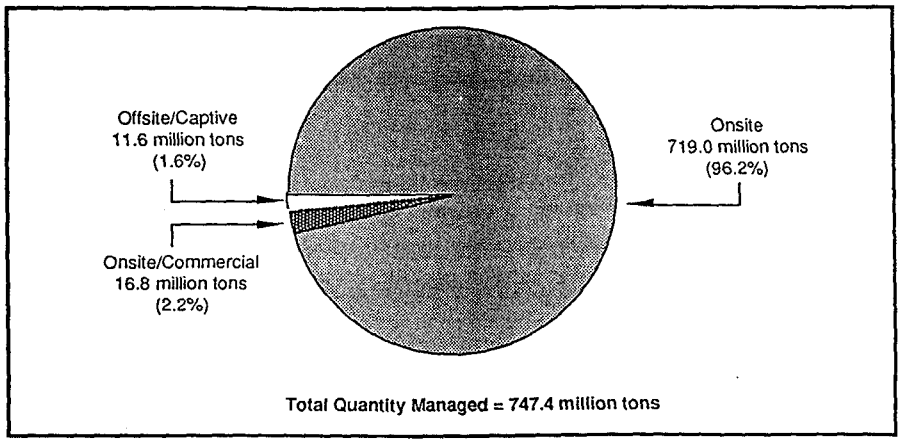
Table II
Hazardous Waste Management Technology Usage by Industrial Sector (2 digit SIC code)

Management Method	Major Contributor	% Contribution by major contributor
Metal recovery	Primary metal	34
Solvent recovery	Chemical manufacturing	21
Other recovery	Nonelectrical machinery	38
Fuel blending	Chemical manufacturing	46
Reuse as fuel	Chemical manufacturing	53
Incineration	Chemical manufacturing	83
Solidification	Chemical manufacturing	29
Land treatment	Petroleum industry	83
Wastewater treatment	Chemical manufacturing	46
Disposal Impoundment	Chemical manufacturing	79
Surface impoundment	Chemical manufacturing	86
Landfill	Metal fabrication	20
Waste pile	Transportation equipment	30
Underground injection	Chemical manufacturing	60

Table III. Distribution of Incinerator Types in Use in 1986

Incinerator Type	No. of Incinerators
Liquid Injection	129
Rotary Kiln	27
Kiln+Liquid Injection	23
Two Stage	20
Fixed Hearth	17
Multiple Hearth	7
Fluidized Bed	7
Infrared	0
Fume/Vapor	4
Pyrolytic	9
Other	17
TOTAL[a]	260

[a]This is the number of incinerator units which is different from the number of management facilities with incinerators (see Table I).



Note:
- Hazardous waste managed onsite was managed by the generator of the waste.
- Hazardous waste managed commercially was managed offsite by a company under different ownership than the generator of the waste.
- Hazardous waste managed captively was managed offsite by a company under the same ownership as the generator of the waste.

Figure 18. Quantity of Hazardous Waste that was Managed Onsite, Commercially, and Captively in 1986.

reason is that the waste generators could report their waste types by as many as five different codes which best described the generated waste. These codes were entered in the database by alphabetic order rather than in an order which best describes the waste type. Thus, reporting the distribution of managed waste by a single type involves more uncertainties than the distribution by industry sectors generating wastes. Figures 1a-16a, however, give some idea about the major types of wastes managed by different techniques.

Moving on to Figures 1b-16b (results summarized in Table II), we see that chemical manufacturing is the dominant user of most technologies. Some of the exceptions to this pattern are logical. For example, the primary metals industry is a disproportionately large user of metal recovery operations. Other exceptions require explanation. For example, in 1986 the petroleum refining industry used a practice called landfarming in which petroleum wastes are mixed with surface soil and biodegraded (3). Finally, the geographical distribution of management units shown in Figures 1c-16c show that most incineration, reuse as fuel, land treatment and underground injection occur in EPA Region VI. Regions VII and VIII are notable for their lack of hazardous waste management activity. These geographical distributions of management practices closely mirror the geographical distribution of waste generation (1). As shown in Figure 18, 96% of hazardous waste is managed on site.

CONCLUSION

This paper has presented data from the National Hazardous Waste Survey on usage patterns for waste management technologies. Due to space limitations, we are unable to present the true depth of the survey data. For example, we have combined all data on waste incineration, however, as shown by the incineration data in Table III (4), the survey can be used to examine more details in any of the management technologies.

The data presented in Figures 1-16 are the best estimates available for the distribution of waste managed by different techniques by waste type and by industry category. The data must be used with caution, however, due to the following uncertainties,

- Any national survey of this scope will contain some inaccuracies in data reporting.

- In the Generator Survey (the basis for Figures 1a-16a and 1b-16b) a single waste flow rate, equal to the rate of waste generation, is reported for the entire treatment train. Thus, if a waste stream was managed by a sequence of operations such as solvent recovery, metal recovery and incineration, the waste flow rate to each process would not be known. Only the total waste generation rate is certain. This introduces some uncertainties in Figures 1-16. However, comparison of the TSDR and Generator Survey data indicates that this uncertainty is not significant.

- The type of waste generated at a site, could be reported using up to five different waste codes. These codes were arranged in the database in alphabetic order. This ordering introduces limitations in the interpretation of the results of the major waste types.

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(1) U.S. Environmental Protection Agency, "1986 National Survey of Hazardous Waste Treatment, Storage, Disposal and Recycling Facilities", EPA/530-SW-88-035.

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(3) Bush, B. L. and Levine, G., Hazardous Waste and Hazardous Materials (this issue).

(4) Behmanesh, N., "Modeling and Optimization of Hazardous Waste Incineration", Ph.D. Thesis, University of California, Los Angeles, 1990.