Characterization of Class A Low-Level Radioactive Waste 1986-1990

Executive Summary

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Prepared by
J-C Dehmel, D. Loomis, J. Mauro, S. Cohen & Associates, Inc.
M. Kaplan, Eastern Research Group, Inc.

S. Cohen & Associates, Inc.
1355 Beverly Road, Suite 250
McLean, VA 22101

Subcontractor:
Eastern Research Group, Inc.
110 Hartwell Avenue
Lexington, MA 02173

Prepared for
Division of Regulatory Applications
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FOREWORD

This report characterizes Class A Low Level waste shipped for disposal from 1986 through 1990. It was developed as part of a Nuclear Regulatory Commission (NRC) sponsored study to develop a technical information base useful to persons and organizations involved in the management and disposal of Low-Level radioactive waste and in the regulation of these activities.

This NUREG report is not a substitute for NRC regulations, and compliance is not required. The approaches and/or methods described in this NUREG are provided for information only. Publication of this report does not necessarily constitute NRC approval or agreement with the information contained herein.

A handwritten signature in cursive script, reading "Donald A. Cool", followed by a horizontal line.

Donald A. Cool, Chief
Radiation Protection and Health
Effects Branch
Division of Regulatory Applications
Office of Nuclear Regulatory Research

ABSTRACT

Under contract to the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, the firms of S. Cohen & Associates, Inc. (SC&A) and Eastern Research Group (ERG) have compiled a report that describes the physical, chemical, and radiological properties of Class-A low-level radioactive waste. The report also presents information characterizing various methods and facilities used to treat and dispose non-radioactive waste.

The characterization of Class-A low-level waste is based primarily on information contained in the Manifest Information Management System (MIMS), an electronic database compiled by the National Low-Level Waste Management Program. The Program is managed by EG&G Idaho, Inc. for the Department of Energy. Supplementary sources of information include reports and studies conducted under the auspices of the Nuclear Regulatory Commission, Department of Energy, regional low-level waste Compacts and unaffiliated States, and trade organizations. The database characterizes low-level waste shipped for disposal from 1986 to 1990.

A database management program was developed for use in accessing, sorting, analyzing, and displaying the electronic data provided by EG&G. The program was used to present and aggregate data characterizing the radiological, physical, and chemical properties of the waste from descriptions contained in shipping manifests. The data thus retrieved are summarized in tables, histograms, and cumulative distribution curves presenting radionuclide concentration distributions in Class-A waste as a function of waste streams, by category of waste generators, and regions of the United States.

The report also provides information characterizing methods and facilities used to treat and dispose non-radioactive waste, including industrial, municipal, and hazardous waste regulated under Subparts C and D of the Resource Conservation and Recovery Act (RCRA). The information includes a list of disposal options, the geographical locations of the processing and disposal facilities, and a description of the characteristics of such processing and disposal facilities.

Volume 1 contains the Executive Summary, Volume 2 presents the Class-A waste database, Volume 3 presents the information characterizing non-radioactive waste management practices and facilities, and Volumes 4 through 7 contain Appendices A through P with supporting information.

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Appendices A through P present additional information for the executive Summary (Vol. 1) and Main Report (Vol. 2 and 3). The appendices are contained in the following volumes:

Volume 4:

- A Sample Shipping Manifest Forms
- B Low-Level Waste Data Manager Program Description
- C Waste Forms and Radionuclide Concentrations Compacts
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- D Waste Forms and Radionuclide Concentrations - Analyses
at the container level for Selected Waste Forms; Beatty
and Richland 1988-1990
- E Radionuclide Concentrations by Compact Regions and
States - Shipment-level Analyses: All Disposal Sites
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Volume 5:

- F Waste Radionuclide Concentrations by Compact Regions and
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Non-Brokered Wastes Aggregate Practices 1986-1990

Volume 6:

- G Location of Major Waste Generators and Compact Regions
and States Population Distributions
- H Fuel Fabrication Facilities - Shipment-level Analyses
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Volume 7:

- K Processed and Brokered Wastes - Selected Waste Forms
and Radionuclides: Container-level Analyses Aggregate
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- L Population Information Pertaining to RCRA Subparts C and D
Facilities
- M Municipal Solid Waste Landfills in 1986 Survey
- N State Comments on Landfill Capacity
- O Municipal Solid Waste Landfills - 1992 Listing
- P Cross-Reference List of Geographical Locations for Treatment
and Disposal Facilities

PREFACE

Section 10 of the Low-Level Radioactive Waste Policy Amendments Act (LLRWPA) of 1985 directed the Commission to develop criteria and procedures to act upon petitions "to exempt specific radioactive waste streams from regulations ... due to the presence of radionuclides ... in sufficiently low concentrations or quantities as to be below regulatory concern." The Commission responded to this statutory provision by issuing a policy statement on August 29, 1986 (51 FR 30839) that contained criteria for evaluating such petitions. On December 2, 1986 (51 FR 43367), the Commission published an advance notice of proposed rulemaking (ANPR) entitled "Radioactive Waste Below Regulatory Concern: Generic Rulemaking" (RIN 3150-AC35). In July 1990, the Commission issued a second policy statement addressing the below regulatory concern issue, "General Statement of Policy on Below Regulatory Concern," July 3, 1990 (55 FR 27522).

In July 1988, the NRC's Office of Nuclear Regulatory Research contracted S. Cohen & Associates (SC&A) to develop technical information concerning Class A low-level radioactive waste which could be used to support NRC technical evaluations of petitions for exempt waste streams. In May 1990, the contract was modified to include the development of information which could be used in establishing a basis for a generic NRC rule governing the disposal of radioactive waste determined to be Below Regulatory Concern (BRC).

In October 1992, the Congress enacted the Energy Policy Act of 1992. Section 2901 of the Act revoked the Commission's 1986 and 1990 BRC Policy Statements, and in August 1993, the Commission formally withdrew the two BRC Policy Statements. The Commission also terminated the rulemaking action that was initiated to implement the 1986 BRC Policy and withdrew the December 2, 1986 ANPR.

Although it effectively revoked the 1986 BRC Policy Statement, Section 2901 of the Energy Policy Act did not either (1) explicitly remove the Commission's obligation under Section 10 of the Low-Level Radioactive Waste Policy Amendments Act of 1985 to develop criteria and procedures for evaluating exemption requests for specific radioactive waste streams on an expedited basis, or (2) revoke the Commission's authority under the Atomic Energy Act to exempt classes of materials from licensing.

By early 1993, SC&A had already accumulated a substantial amount of information concerning Class A low-level waste. Since the information contained in this report should be useful to the NRC staff and others involved in the regulation or disposal of low-level radioactive waste, the NRC, in July 1993, authorized SC&A to compile and present this information in a NUREG/CR report.

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In addition, we would like to thank Mr. Ronald Fuchs and Ms. Miriam Muneta of EG&G Idaho, Inc. for their assistance in generating the low-level waste database for this project.

EXECUTIVE SUMMARY REPORT

1.0 PURPOSE AND SCOPE OF STUDY

The U.S. Nuclear Regulatory Commission (NRC) has initiated this study to further refine the characterization of Class A, low-level radioactive waste, as defined in 10 CFR, Parts 61.55 and 61.56. This report complements the information presented in an earlier NRC study, titled: Characteristics of Low-Level Waste Disposed During 1987 Through 1989, NUREG-1418 (NRC90). The characterization of Class A waste is based on information contained in the Manifest Information Management System (MIMS), an electronic database compiled by EG&G Idaho, Inc. for the Department of Energy (DOE) under the National Low-Level Waste Management Program. This report includes:

- (1) A description of the physical, chemical, and radiological properties of low-level waste, and likely variations in these properties.
- (2) Tabular and graphical information presenting radionuclide concentration distributions in various waste streams.
- (3) A list of the major generators of Class A waste, their geographical locations, and annual waste volumes and activity levels shipped for disposal.

The report also provides information describing current methods and facilities being used to treat and dispose of waste, including industrial, municipal, and hazardous waste regulated under Subparts C and D of the Resource Conservation and Recovery Act (RCRA). This information includes:

- (1) A list of disposal options for waste regulated under Subparts C and D of RCRA.
- (2) The geographical locations of some of the major processing and disposal facilities and other related sites.
- (3) A description of processing and disposal facilities, including geological and hydrological characteristics, ground and surface water usage, and topographical and meteorological data, when available.
- (4) A description of population demographics around such facilities and occupational work force.

In addition to the Executive Summary (Volume 1), this report consists of six volumes, the Main Report (Volumes 2 and 3) and Appendices A through P, contained in Volume 4 through 7.

2.0 CHARACTERIZATION OF CLASS A LOW-LEVEL RADIOACTIVE WASTE

2.1 Technical Approach and Methods

The characterization of Class A low-level waste provided in this report is based primarily on the information contained in the Manifest Information Management System (MIMS) compiled by EG&G Idaho, Inc. (EG&G) for the DOE under the National Low-Level Waste Management Program. Other sources of information include reports and studies conducted under the auspices of the NRC, DOE, regional low-level waste Compacts and unaffiliated States, and trade organizations (OTA89, NRC83a, NRC83b, NRC85, NRC90, NRC92, CDH89, DOE91, DOE90, EGG89, EGG90, EGG91, EPR88, ICR77, IDN90, NUM90). The MIMS low-level waste data, purchased from EG&G, cover the period of January 1986 to November 1990 (MUN90, MUN91).

The MIMS includes information transcribed from individual shipping manifests, which document waste shipped to the three low-level radioactive waste disposal sites: Barnwell, South Carolina; Beatty, Nevada; and Richland, Washington. This information includes radionuclides, activity levels and concentrations; chemical and physical forms; and waste generator identification codes. The waste generator codes identify the generators by types and locations without divulging their identities. Waste generators are classified as academic, medical, government, industrial, or utility.

It should be noted that a fourth disposal site (Envirocare, located in Utah) has been allowed to receive low specific activity waste, in addition to those containing naturally occurring radionuclides. However, this information has not been captured in the MIMS database and is not addressed here.

Throughout the report, the characterization of Class A waste is provided at two levels of resolution, the "shipment-level" and the "container-level." Throughout this report, the terms:

- "Shipment-level" means that the electronic data available for a given shipment have been aggregated such that information pertaining to individual containers constituting the shipment is not provided. Shipment-level data consist of the total waste volume and inventory of individual radionuclides present in each shipment.
- "Container-level" data means that the electronic data include information on each container in a given shipment, i.e., the inventory of all radionuclides and the waste volume of each container.

Container-level data are the most useful, since they provide the most comprehensive information with which to derive individual radionuclide concentration estimates, as opposed to the diluted

data that result from shipment-level averages. Accordingly, container-level data provide a higher level of resolution regarding the variability of the concentrations of individual radionuclides.

Shipment-level data are available in electronic form for five years, from 1986 to 1990, for all three disposal sites (MUN90, MUN91). Container-level data, however, are available only for Beatty and Richland from 1988 to 1990. In both cases, the 1990 data provided in this report reflect information posted by the end of November 1990.

For brokered waste shipments, the database does not allow to apportion radionuclide and activity levels directly to each generator or category of waste generators making up the shipment. In addition, brokered shipments often include waste from out-of-region generators, making it difficult to assign shipments to specific Compacts or unaffiliated States.

The database obtained from EG&G consists of 18,776 shipment-level records. Of these, about 15 percent provide information at the container-level. The database includes 103,355 container-level records. Each record, whether at the shipment or container-level, provides information on the individual radionuclides contained in the shipments. The database contains a total of 705,387 radionuclide citations.

A database management program was developed to access, sort, and display the electronic data. The program was used to present and aggregate data characterizing the radiological, physical, and chemical properties of the waste from descriptions contained in the shipping manifests. The data thus retrieved is summarized in tables, histograms, and cumulative distribution curves. The program structure uses dBase/Clipper to retrieve the data and perform the sorts. The operating program and its supporting files are contained in 29 files consisting of 720.6 kilobytes and 20.5 megabytes of data, respectively. In total, the electronic files that are the primary basis for this report consist of 57.8 megabytes of data.

2.2 Results - Summary of the Class A Low-Level Radioactive Waste Characteristics

Throughout the report, the data contained in the database at both the container and shipment-level are used to construct radionuclide concentration distributions sorted primarily by category of waste generators, waste streams, and regions of the United States.

The waste generator categories are:

- academic
- government
- industrial
- medical
- nuclear utility

In addition, a separate data sort for brokered waste shipments is provided.

The data were also sorted by regional Compacts or unaffiliated States from which the waste originates. The regions include:

• Northwest	• Appalachian
• Northeast	• Southwest
• Rocky Mountain	• Massachusetts
• Central	• New Hampshire
• Midwest	• New York
• Central Midwest	• Texas
• Southeast	• Vermont
• District of Columbia	• Rhode Island
• Maine	• Puerto Rico

This approach was used for two reasons. First, it serves as a reference source that makes maximum use of the existing database characterizing low-level waste. Second, it offers some insight into the variability of radionuclide concentration distributions by category of waste generators, waste streams and forms, and regions of the United States.

Since this study has been completed, there has been some changes in the makeup of the Compacts. The State of Michigan is no longer in the Midwest Compact, it is now unaffiliated. The State of Wyoming has left the Rocky Mountain Compact and joined the Northwest Compact. The Rocky Mountain Compact has reached an agreement to use the Northwest Compact's disposal site. The State of Texas has agreed to form a Compact with the States of Maine and Vermont. The analyses presented in this report do not reflect these changes, as the database captured practices that predate these realignments.

2.2.1 Overview of the Low-Level Waste Shipped for Disposal in the United States

2.2.1.1 Number of Waste Shipments

Figure 1 presents the total number of direct shipments made by each category of waste generator from 1/86 to 11/90. In this figure, brokered shipments are included under "Industrial" even

Figure 1. Number of Waste Shipments: 1/86 to 11/90

though the shipments include waste produced by all categories of waste generators. By definition, brokered waste include waste handled through brokers or processors. Nuclear utilities, which shipped their waste primarily to Barnwell, made approximately 56 percent of the shipments. Approximately 70 percent of all shipments went to Barnwell over the period covered by this investigation.

Among these shipments, only those to Richland and Barnwell from 1/88 to 11/90 contain data characterizing individual containers in each shipment. As a result, the database containing both shipment and container-level data is limited. For example, the total number of utility shipment records in the database is 10,652 (i.e., 9,308 + 287 + 1,057); however, of this, only 1,408 have container-level data.

Figure 2 presents the fraction of the shipments that can be accessed at the container-level and the total number of containers available in the electronic database. As may be noted, the number of shipments having container-level data is relatively small and varies by category of waste generators.

Overall, only 15 percent of the shipments contain data at the container-level. Specifically, the total number of shipments in the database is 18,776, of which only 2,901 contain data at the container-level. This means that any conclusions about the radionuclide concentration distributions in individual waste containers for specific categories of generators and waste streams must be based on a subset of the entire database. Because of this limitation, the data summaries provided here present radionuclide concentration distributions at both the container and shipment-level to make the maximum use of the available data.

Finally, it must be pointed out that all waste radionuclide concentrations are based on the overall container volume or weight and not the actual waste volume or mass. The database does not provide the means to resolve the net volume or weight of the waste from the shipping manifest entries.

2.2.1.2 Waste Activity and Volume

Figure 3 presents the total waste volume, and Figure 4 presents the total activity of radioactive waste shipped for disposal for each category of waste generators and by year, from 1986 to 1990. All low-level waste, including Class A, B, and C, brokered and non-brokered, are included as well. Figures 5 and 6 present the same information for Class A waste alone. Class A waste constitutes about 95 percent of the volume, but only about five percent of the activity of the total waste. Tables 1 and 2 provide further information.

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Figure 2. Container Level Data: 1/86 to 11/90

Figure 3. All Wastes Shipped: Volume Trends (m³)

Figure 4. All Wastes Shipped: Activity Trends (Ci)

Figure 5. Class A Waste Shipped: Volume Trends (m³)

Figure 6. Class A Waste Shipped: Activity Trends (Ci)

Table 1 Yearly Activity (Ci) and Waste Volumes (m³) of All Waste Shipped for Disposal^(a)

<u>Year</u>	<u>Academic</u>	<u>Government</u>	<u>Medical</u>	<u>Industrial</u>	<u>Utility</u>	<u>Total</u>
<u>1986</u>						
Volume	8.15E+2	2.29E+3	6.75E+2	1.80E+4	2.93E+4	5.11E+4
Activity	1.07E+2	4.90E+3	2.60E+1	5.82E+4	1.71E+5	2.34E+5
<u>1987</u>						
Volume	1.34E+3	3.75E+3	8.00E+2	1.89E+4	2.80E+4	5.28E+4
Activity	1.07E+2	7.17E+3	3.55E+1	4.25E+4	1.70E+5	2.00E+5
<u>1988</u>						
Volume	1.25E+3	2.47E+3	5.96E+2	1.32E+4	2.29E+4	4.04E+4
Activity	2.26E+3	9.49E+3	8.09E+1	3.44E+4	2.13E+5	2.59E+5
<u>1989</u>						
Volume	1.84E+3	3.22E+3	9.66E+2	1.61E+4	2.39E+4	4.60E+4
Activity	1.94E+3	1.26E+4	1.49E+2	1.27E+5	7.25E+5	8.67E+5
<u>1990</u>						
Volume	1.38E+3	2.05E+3	6.45E+2	1.01E+4	1.82E+4	3.24E+4
Activity	1.09E+3	1.01E+4	5.95E+1	1.03E+5	4.33E+5	5.47E+5
<u>Total</u>						
Volume	6.63E+3	1.38E+4	3.68E+3	7.63E+4	1.22E+5	2.22E+5
Activity	5.50E+3	4.43E+4	3.51E+2	3.65E+5	1.61E+6	2.03E+6

(a) Includes Class A, B, and C, brokered, and non-brokered waste. Data extracted from NUREG-1418 (NRC90); DOE/LLW-66T, (EGG87); DOE/LLW-132 (EGG91); and DOE/EG&G MIMS on-line service (MIM91, EGG84). To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

Table 2 Estimated Yearly Activity (Ci) and Waste Volumes (m³) of Class A Waste Shipped for Disposal^(a)

<u>Year</u>	<u>Academic</u>	<u>Government</u>	<u>Medical</u>	<u>Industrial</u>	<u>Utility</u>	<u>Total</u>
<u>1986</u>						
Volume	8.15E+2	2.29E+3	6.75E+2	1.80E+4	2.93E+4	5.11E+4
Activity	1.07E+2	4.90E+3	2.60E+1	5.82E+4	1.71E+5	2.34E+5
<u>1987</u>						
Volume	1.39E+3	3.79E+3	7.62E+2	1.89E+4	2.61E+4	5.09E+4
Activity	1.03E+2	2.63E+2	3.47E+1	3.80E+3	2.19E+4	2.61E+4
<u>1988</u>						
Volume	1.25E+3	2.46E+3	5.98E+2	1.31E+4	2.16E+4	3.90E+4
Activity	1.50E+2	3.03E+2	8.10E+1	3.81E+3	2.43E+4	2.82E+4
<u>1989</u>						
Volume	1.83E+3	3.20E+3	9.66E+2	1.60E+4	2.27E+4	4.46E+4
Activity	2.98E+2	2.08E+2	1.46E+2	4.89E+3	2.31E+4	2.84E+4
<u>1990</u>						
Volume	1.18E+3	1.66E+3	5.66E+2	7.74E+3	1.09E+4	2.20E+4
Activity	2.65E+2	9.86E+3	5.61E+1	8.19E+3	7.63E+3	2.60E+4

(a) Includes Class A brokered and non-brokered waste. The 1986 data were extracted from the 1986 State by-State Assessment (EGG87) and database. For 1987 to 1989, data extracted from NUREG-1418 (NRC90). For 1990, data extracted from low-level waste MIMS database on-line service (EGG84, MIM91). To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

2.2.1.3 Radionuclides

The analyses of the data revealed that more than 90 percent of Class A waste activity consists of the following radionuclides:

H-3	Mn-54	Co-60	Zr-95	I-125	U-238
C-14	Fe-55	Ni-63	Ru-103	I-131	
P-32	Fe-59	Zn-65	Ru-106	Cs-134	
S-35	Co-57	Kr-85	Ag-110m	Cs-137	
Cr-51	Co-58	Nb-95	Sb-124	Ra-226	

2.2.1.4 Radionuclide Concentrations

Radionuclide concentrations were derived by conducting analyses with specified search parameters. The results are presented in the form of histograms and cumulative distribution curves for the principal radionuclides captured in each sort. The histograms and cumulative distributions present average and range of concentrations, standard and average deviations, kurtosis and skewness, and the number of data points on which radionuclide concentration ranges are based. The descriptive statistical parameters provide the means to assess how radionuclide concentrations vary. In addition, each sort includes a summary sheet giving additional information, including the total number of shipping and container records captured in the sort, weight of waste shipments, waste densities, and total and fractional waste volumes and activity levels.

All waste radionuclide concentrations were derived using the overall container volume or weight and not the actual waste volume or mass. The database does not provide the means to resolve the net volume or weight of each waste container.

Waste shipped by brokers or waste processors are not included in these analyses because the brokered data, available at the container-level, are aggregated in a manner that precludes sorting by category of waste generators.

The radionuclide concentrations of Class A waste varied widely as a function of waste stream, with concentrations ranging over eight orders of magnitude, from 10^{-6} to 10^{+2} Ci/m³ depending upon the radionuclides. For some waste streams, however, radionuclide concentrations tend to cluster over a narrower range, from about 10^{-3} to 10^{+0} Ci/m³. A review of some of the data which follow and that are contained in the subsequent volumes will reveal the highly variable nature of radionuclide concentrations. The following typifies the range of concentrations for the five categories of waste generators.

Generator Sector	Range of Concentrations - Ci/m ³	
	<u>Average</u>	<u>Maximum</u>
Academic	10 ⁻² - 10 ⁻⁴	10 ⁻³ - 10 ⁻¹
Government	10 ⁻⁵ - 10 ⁻⁴	10 ⁻³ - 10 ⁻²
Industrial	10 ⁻⁵ - 10 ⁺¹	10 ⁻² - 10 ⁺²
Medical	10 ⁻⁴ - 10 ⁻²	10 ⁻³ - 10 ⁺⁰
Utility	10 ⁻³ - 10 ⁻¹	10 ⁻² - 10 ⁺¹

2.2.1.5 Waste Volume and Activity Shipped For Disposal

The volume of waste shipped per waste generator from 1986 to 1990 ranged from less than one to several thousand cubic meters. The activity shipped per waste generator from 1986 to 1990 ranged from a few millicuries to several thousand Curies.

2.2.1.6 Waste Streams

Although the waste streams vary widely, the following types of waste were most frequently reported:

- compacted dry active waste
- non-compacted dry active waste
- absorbed and stabilized liquids
- biological tissues and animal carcasses
- spent de-watered resins
- spent scintillation fluid
- solidified liquid
- evaporator bottoms
- non-cartridge filter
- solidified oils
- activated contaminated hardware
- activated contaminated concrete

Other waste streams are also addressed in this report, but to a lesser degree because of their limited usefulness.

2.2.2 Academic Waste Generators

Academic institutions include universities, colleges, and other specialized teaching facilities using radioactive materials. Low-level radioactive waste produced by academic institutions are associated with such activities as medical training and research, health care administration, industrial and materials testing, and basic and applied research in various technical and scientific fields (e.g., physics, chemistry, and biology).

Academic facilities generate a wide spectrum of waste. The following Class A waste streams are routinely produced by the academic sector:

- dry solids
- compacted and non-compacted dry active waste
- animal carcasses and other forms of biological waste
- aqueous waste in vials and sorbents
- solidified and absorbed aqueous liquids

The most frequently reported radionuclides include H-3, C-14, S-35, Cr-51, P-32, Co-60, Se-75, I-125, and I-131.

The waste volumes and activity levels shipped for disposal by the academic sector are shown in Table 3 and Figures 7 and 8. The data include all classes of both brokered and unbrokered waste.

2.2.2.1 Waste Characterization - Container-Level

A search of the database, conducted at the container-level, captured the following data for all direct shipments of Class A waste and all academic waste generators from 1988 to 1990:

- 19 shipping manifests
- 2,452 container records
- 297 cubic meters of waste
- 155,600 kg of waste, 0.52 g/cm³ average density
- 23.3 Ci of total activity, 0.08 Ci/m³

The results of this search represent about seven percent of the volume and 0.4 percent of the activity shipped by academic waste generators. The percentage of the activity captured in the sort is much smaller than the percentage of the volume because about 95 percent of the activity in low-level waste is contained in Class B and C waste, which comprise about five percent of the volume. For the same reason, the average gross radionuclide concentration in the sort is about 0.08 Ci/m³, while the average gross radionuclide concentration in all academic waste (from 1988 to 1990) is about 1.2 Ci/m³.

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	Class A Limits (Ci/m ³)	Activity Shipped (Ci)	Concentration (Ci/m ³)		1%ile	10%ile	90%ile	99%ile
			Median	Average				
C-14	0.8	5.0E-01	4.0E-04	2.04E-03	4.7E-06	2.35E-05	4.94E-03	2.1E-02
Ca-45	700	7.9E-02	4.2E-04	1.47E-03	4.7E-06	4.24E-05	4.71E-03	1.3E-02
Cr-51	700	1.3E+00	1.9E-03	8.70E-03	4.7E-06	9.42E-05	2.35E-02	8.8E-02
H-3	40	1.0E+01	6.1E-03	3.35E-02	4.2E-05	5.32E-04	7.48E-02	3.1E-01
I-125	700	5.4E+00	5.8E-03	1.36E-02	4.7E-06	1.41E-04	3.35E-02	1.2E-01
I-131	700	3.3E-01	4.7E-03	1.06E-02	4.7E-06	1.04E-04	2.92E-02	9.8E-02
P-32	700	1.8E+00	4.9E-03	1.29E-02	4.7E-06	3.77E-04	2.59E-02	1.1E-01
S-35	700	3.3E+00	4.9E-03	1.21E-02	4.7E-06	1.88E-04	2.92E-02	9.6E-02

Table 3 Academic Waste Volume and Activity by Compact
Regions and States - Aggregate Practices from 1986
to 1990^(a)

<u>Compact/State</u>	<u>Volume Vol. (m³)</u>	<u>Percent</u>	<u>Activity Act. (Ci)</u>	<u>Percent</u>
Northwest	333	4.6	57	1
Rocky Mountain	278	3.8	537	10
Central	33	0.5	6	0.1
Midwest	927	12.7	296	5.6
Central Midwest	242	3.3	16	0.3
Southeast	1,210	16.6	1,250	23.5
Northeast	890	12.2	50	1
Appalachian	382	5.2	34	0.7
Southwest	1,960	26.9	200	3.8
District of Columbia	14	0.2	1	<0.1
Maine	4	<0.1	0.1	<0.1
Massachusetts	113	1.6	87	1.6
New Hampshire	4	<0.1	57	1.1
New York	410	5.7	2,640	50
Rhode Island	28	0.4	1	<0.1
Texas	410	5.7	73	1.4
Vermont	34	0.5	1	0.2
Total	<u>7,272</u>	--	<u>5,306</u>	--

(a) Data extracted from database. Waste volumes and activity levels are rounded off. Percent may not add up to 100% because of rounding off. Puerto Rico did not dispose of any waste during the given period. To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

Figure 7 Academic Waste Volume: 1986 to 1990

Figure 8. Academic Waste Activity: 1986 to 1990

For the principal radionuclides, the results indicate that the average concentrations are on the order of 10^{-2} to 10^{-3} Ci/m³. Interestingly, the 90th percentile values are consistently about a factor of two to three higher than the average, while the 10th percentile values are consistently about two orders of magnitude lower than the average. The 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, yielding a concentration of $4.7\text{E-}06$ Ci/m³ for a 55-gallon drum. The 99th percentile values appear to be about a factor of five higher than the 90th percentile values. The results also indicate that radionuclide concentrations are several orders of magnitude below the limits set forth in 10 CFR 61.55 for Class A waste.

2.2.2.2 Waste Characterization - Shipment-Level

A search of the database, at the shipment-level, captured the following data for all direct shipments of Class A waste and all academic waste generators from 1986 to 1990:

- 438 shipping manifests
- 2,037 cubic meters of waste
- $1.16\text{E}+06$ kg of waste, 0.57 g/cm³ average density
- 170 Ci of total activity, 0.08 Ci/m³

This search represents about 28 percent of the volume and three percent of the activity of the waste shipped for disposal by academic waste generators. The balance was shipped by brokers and processors and includes a very small amount of Class B and C waste. In addition, the average gross radionuclide concentration in the sort is about 0.08 Ci/m³, while the average gross radionuclide concentration in all academic waste is about 0.73 Ci/m³. These results are consistent with those obtained at the container-level. A small percentage of activity is captured relative to the volume because the sorts do not include Class B and C waste, which contain most of the radioactivity.

The results of the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	10CFR61 Class A Limits	Activity Captured (Ci)	Concentration (Ci/m ³)		1%ile or min.	10%ile	90%ile	99%ile or max.
			Median	Average				
C-14	0.8	$3.3\text{E}+00$	$4.5\text{E-}04$	$1.2\text{E-}03$	$1.4\text{E-}05$	$3.4\text{E-}05$	$3.7\text{E-}3$	$9.5\text{E-}03$
Ca-45	700	$7.5\text{E-}01$	$1.6\text{E-}04$	$5.2\text{E-}04$	$5.6\text{E-}07$	$8.3\text{E-}06$	$1.1\text{E-}03$	$1.0\text{E-}02$
Cr-51	700	$5.2\text{E}+00$	$1.0\text{E-}03$	$2.6\text{E-}03$	$2.1\text{E-}07$	$3.6\text{E-}05$	$9.0\text{E-}03$	$1.4\text{E-}02$
H-3	40	$8.8\text{E}+01$	$6.8\text{E-}03$	$2.5\text{E-}02$	$6.8\text{E-}05$	$6.8\text{E-}04$	$5.1\text{E-}02$	$2.5\text{E-}01$
I-125	700	$2.4\text{E}+01$	$5.7\text{E-}03$	$8.2\text{E-}03$	$3.8\text{E-}05$	$5.3\text{E-}04$	$1.7\text{E-}02$	$3.5\text{E-}02$
P-32	700	$2.3\text{E}+01$	$7.9\text{E-}03$	$1.2\text{E-}02$	$2.1\text{E-}06$	$5.6\text{E-}04$	$3.0\text{E-}02$	$6.5\text{E-}02$
S-35	700	$1.5\text{E}+01$	$3.3\text{E-}03$	$7.1\text{E-}03$	$5.6\text{E-}06$	$1.1\text{E-}04$	$1.8\text{E-}02$	$4.2\text{E-}02$

2.2.2.3 Location of Waste Generators

The locations of the major academic waste generators are identified by city, county, and state in Appendix G-1.

2.2.3 Government Waste Generators

Government institutions include research and testing laboratories, environmental laboratories, medical facilities, military installations, and other types of facilities, such as warehouses, research stations, airports, and shipping ports. The database does not provide the means to identify the generators by types of government agencies, e.g., local, state, or federal. Low-level radioactive waste produced by government institutions is generally associated with industrial research, materials testing, organic and inorganic chemistry, geological and mineral exploration, and basic and applied research in various scientific and technical fields. As with the other categories of generators, the activities that result in waste generation change with the implementation of new research programs, assignment of new missions, legislative mandates, etc.

The most frequently reported waste streams include:

- dry solids
- solidified oils
- compacted and non-compacted trash
- absorbed and stabilized liquids
- aqueous liquids in vials and sorbents
- non-cartridge filter media
- animal carcasses
- solidified chelates
- sealed sources
- activated and contaminated hardware and concrete

In many respects, waste generated by government institutions are similar to those generated by academic facilities and some industrial licensees.

The most frequently reported radionuclides include H-3, C-14, Mn-54, Fe-55, Co-58, Co-60, Ni-63, Kr-85, Po-210, Pm-147, Ra-226, U-238, depleted uranium, and natural uranium and thorium.

Waste volumes and activities shipped by government institutions are shown in Table 4 and Figures 9 and 10 for 1986 to 1990.

Table 4 Government Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 to 1990^(a)

<u>Compact/State</u>	<u>Volume</u>		<u>Activity</u>	
	<u>Vol. (m³)</u>	<u>Percent</u>	<u>Act. (Ci)</u>	<u>Percent</u>
Northwest	1,650	12	364	0.8
Rocky Mountain	13	0.1	1,890	4.2
Central	36	0.3	489	1.1
Midwest	915	6.8	494	1.1
Central Midwest	211	1.6	1,900	4.3
Southeast	4,950	37	11,800	26.4
Northeast	176	1.3	1,910	4.3
Appalachian	1,940	14.4	17,400	38.9
Southwest	914	6.8	2,700	6.0
District of Columbia	29	0.2	15	<0.1
Maine	368	2.7	20	<0.1
Massachusetts	179	1.3	145	0.3
New Hampshire	0.2	<0.1	11	<0.1
New York	279	2.1	530	1.2
Rhode Island	1	<0.1	9	<0.1
Texas	1,810	13	5,030	11.3
Vermont	<0.1	<0.1	<0.1	<0.1
Total	13,471	--	44,707	--

(a) Data extracted from database for Class A, B, and C brokered and unbrokered waste. Waste volumes and activity levels are rounded off. Percentages may not add up to 100% because of rounding off. Puerto Rico did not dispose of any waste. To convert volume to cubic feet multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

* Vermont has less than 0.1 m³

Figure 9. Government Waste Volume: 1986 to 1990

* Vermont has less than 0.1 Ci

Figure 10. Government Waste Activity: 1986 to 1990

2.2.3.1 Waste Characterization - Container-Level

A search of the database, conducted at the container-level, captured the following data for all direct shipments of Class A waste by all government waste generators from 1988 to 1990:

- 78 shipping manifests
- 3,297 container records
- 1,488 cubic meters of waste
- $1.01\text{E}+6$ kg of waste, 0.68 g/cm^3 average density
- 34.7 Ci of total activity, 0.023 Ci/m^3

The results of this search represent about 19 percent of the volume and 0.1 percent of the activity of the total waste produced by government waste generators. The percentage of the activity captured in the sort is much smaller than the percentage of the volume because about 95 percent of the activity is contained in Class B and C waste, which makes up about 5 percent of the volume. For the same reason, the average gross radionuclide concentration in the sort is about 0.023 Ci/m^3 , while the average gross radionuclide concentration in all government waste is about 4.2 Ci/m^3 .

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	Class A Limits (Ci/m^3)	Activity Shipped (Ci)	Concentration (Ci/m^3)		1%ile	10%ile	90%ile	99%ile
			Median	Average				
Fe-55	700	$1.3\text{E}+01$	$2.8\text{E}-04$	$4.54\text{E}-03$	$4.7\text{E}-06$	$3.85\text{E}-05$	$5.24\text{E}-03$	$9.0\text{E}-02$
Co-60	700	$1.3\text{E}+01$	$2.7\text{E}-04$	$4.50\text{E}-03$	$4.7\text{E}-06$	$3.77\text{E}-05$	$5.16\text{E}-03$	$9.0\text{E}-02$
Co-58	700	$3.0\text{E}+00$	$1.9\text{E}-05$	$2.51\text{E}-04$	$4.7\text{E}-06$	$4.71\text{E}-06$	$2.97\text{E}-04$	$4.7\text{E}-03$
H-3	40	$2.4\text{E}+00$	$3.0\text{E}-03$	$2.58\text{E}-03$	$2.3\text{E}-04$	$6.78\text{E}-04$	$3.39\text{E}-03$	$4.0\text{E}-03$
Mn-54	700	$2.2\text{E}+00$	$5.2\text{E}-05$	$7.86\text{E}-04$	$4.7\text{E}-06$	$9.42\text{E}-06$	$9.09\text{E}-04$	$1.6\text{E}-02$
Ni-63	3.5^*	$6.5\text{E}-01$	$1.9\text{E}-05$	$2.75\text{E}-04$	$4.7\text{E}-06$	$4.71\text{E}-06$	$2.97\text{E}-04$	$4.9\text{E}-03$
C-14	0.8^{**}	$3.0\text{E}-01$	$9.4\text{E}-06$	$1.88\text{E}-04$	$4.7\text{E}-06$	$4.71\text{E}-06$	$1.79\text{E}-04$	$2.2\text{E}-03$

* For activated metals, the limit is 35 Ci/m^3 .

** For activated metals, the limit is 8.0 Ci/m^3 .

The results indicate that the average radionuclide concentrations are on the order of 10^{-3} to 10^{-4} Ci/m^3 for the major radionuclides. The 90th percentile values are consistently less than a factor of two higher than the average, while the 10th percentile values are consistently about one to two orders of magnitude lower than the average. The 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, resulting in a concentration of $4.7\text{E}-06\text{ Ci/m}^3$ for a 55-gallon drum.

2.2.3.2 Waste Characterization - Shipment-Level

A search of the database, performed at the shipment-level, captured the following data for all direct shipments of Class A waste by all government waste generators from 1986 to 1990:

- 242 shipping manifests
- 4,120 cubic meters of waste
- 2.89×10^6 kg of waste, 0.70 g/cm^3 average density
- 758 Ci of total activity, 0.18 Ci/m^3

The results of this search represent about 30 percent of the volume and 1.7 percent of the activity of the waste shipped for disposal by government generators. The other 70 percent was shipped by brokers and processors and includes some Class B and C waste. In addition, the average gross radionuclide concentration is about 0.18 Ci/m^3 , while the average gross radionuclide concentration in all government waste is about 3.3 Ci/m^3 . A small percentage of activity is captured relative to the total activity shipped because the sort does not include Class B and C waste, which contains most of the radioactivity.

The overall shipment-level radionuclide concentration results are a factor of eight higher than that of the container-level analysis. This inconsistency might be due to one or more improperly coded shipments or containers in the database. For example, one possibility might be a commingled shipment that includes a large number of Class A waste drums and one drum of Class B or C waste. In this instance, the entire shipment might be simply categorized as Class A. Consequently, the higher levels of activity contained in the Class B or C drum would increase the radionuclide concentration. The database does not provide the means to trace the source of such discrepancies.

The results of the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	10CFR61 Class A Limits	Total Activity Captured (Ci)	Concentration (Ci/m^3)		1%ile or min.	10%ile	90%ile	99%ile or max.
			Median	Average				
H-3	40	6.1×10^2	2.1×10^{-4}	3.7×10^{-3}	3.6×10^{-7}	2.1×10^{-5}	1.0×10^{-3}	7.5×10^{-2}
Co-60	700	4.8×10^1	1.4×10^{-3}	4.0×10^{-3}	1.9×10^{-6}	3.8×10^{-4}	6.4×10^{-3}	4.6×10^{-2}
Fe-55	700	4.8×10^1	1.3×10^{-3}	3.8×10^{-3}	7.7×10^{-6}	3.4×10^{-4}	5.6×10^{-3}	4.6×10^{-2}
Mn-54	700	8.2×10^0	2.5×10^{-4}	7.4×10^{-4}	7.4×10^{-7}	5.2×10^{-5}	1.1×10^{-3}	7.8×10^{-3}
Co-58	700	5.4×10^0	7.7×10^{-5}	3.2×10^{-4}	2.9×10^{-6}	2.0×10^{-5}	3.9×10^{-4}	7.6×10^{-3}
C-14	0.8*	3.7×10^0	3.2×10^{-5}	8.8×10^{-4}	7.4×10^{-7}	7.8×10^{-6}	3.6×10^{-4}	2.7×10^{-3}
Ni-63	3.5**	2.6×10^0	7.6×10^{-5}	2.7×10^{-4}	7.0×10^{-7}	1.7×10^{-5}	5.3×10^{-4}	3.5×10^{-3}

* For activated metals, the limit is 8.0 Ci/m^3 .

** For activated metals, the limit is 35 Ci/m^3 .

2.2.3.3 Location of Waste Generators

The locations of the major government waste generators are identified by city, county, and state in Appendix G-1.

2.2.4 Industrial Waste Generators

Industrial facilities include all other commercial waste generators not falling in the institutional or utility category. Industrial facilities are involved in diverse types of activities, such as research, materials testing, chemical production, mineral exploration and processing, and basic and applied research in various scientific disciplines (e.g., physics, chemistry, and biology). Some facilities manufacture consumer products, level and density gauges, and instrumentation and measurement devices that incorporate radioactivity. Industrial facilities also produce radioactive materials that are used as feed stock by other industrial facilities in making various products, e.g., Am-241 for smoke detectors and depleted uranium for military munitions. In addition, the industrial category includes fuel fabrication facilities.

It should be noted that this category also includes waste brokers and processors. However, the analyses were conducted only for non-brokered waste. Consequently, the analyses captured only internally-generated waste (as a licensee) and not those handled for other facilities through commercial services.

Industrial facilities generate a wide spectrum of waste. Such waste include:

- dry solids
- solidified liquids
- sorbed aqueous liquids
- compacted dry active waste
- other unspecified waste materials
- aqueous liquids in vials and sorbents
- cartridge filter media
- animal carcasses in lime and sorbents
- non-compacted dry active waste
- solidified chelates
- solidified resins
- other types of biological waste
- gaseous waste
- solidified oils
- non-sorbed aqueous liquids
- non-aqueous liquids in vials and sorbents
- de-watered resins
- activated metals and concrete

In some respect, these waste streams are similar to those associated with other waste generators, i.e., those involved in biomedical research. The most frequently reported radionuclides by industrial facilities include H-3, C-14, Co-60, Ra-226, Pu-241, U-238, and natural uranium and thorium.

Waste activity and volumes for each Compact and unaffiliated State are shown in Table 5 and Figures 11 and 12, based on waste shipments received at the three disposal sites from 1986 to 1990.

2.2.4.1 Waste Characterization - Container-Level

A search of the database, conducted at the container-level, captured the following data for all direct shipments of Class A waste and all industrial waste generators from 1988 to 1990:

- 43 shipping manifests
- 2,535 container records
- 796 cubic meters of waste
- 529,800 kg of waste, 0.67 g/cm³ average density
- 4,240 Ci of total activity, 5.3 Ci/m³

The results of this search represent about two percent of the waste volume and 1.6 percent of the total activity shipped by industrial waste generators. Unlike the other categories of waste generators, the percentages of the total waste volume and activity captured by the sort are almost the same. This indicates that the activity contained in Class B and C waste does not constitute a large portion of the total activity shipped for disposal. In addition, the sort's average gross radionuclide concentration is about the same as that in industrial waste from 1988 to 1990, 5.3 Ci/m³ vs 6.7 Ci/m³, respectively. The following summarizes the concentration distributions of the principal radionuclides:

Radionuclide	Class A Limits (Ci/m ³)	Activity Shipped (Ci)	Concentration (Ci/m ³)		1%ile	10%ile	90%ile	99%ile
			Median	Average				
H-3	40	3.4E+03	4.9E-01	8.62E+00	4.7E-06	4.71E-05	3.42E+01	3.6E+01
C-14	0.8*	1.9E+02	7.0E-01	4.26E-01	4.7E-06	4.24E-06	7.77E-01	7.9E-01
Ra-226	**	5.7E+00	2.1E+00	1.36E+00	4.7E-06	4.71E-06	2.33E+00	2.4E+00
Co-57	700	2.3E+00	6.1E-03	1.86E-02	1.9E-05	4.71E-04	3.70E-02	1.0E-01
Co-60	700	2.1E+00	5.2E-05	8.90E-03	4.7E-06	4.71E-06	1.99E-02	1.7E-01
I-125	700	9.4E-01	9.4E-03	3.99E-02	4.7E-06	2.90E-03	1.18E-01	4.2E-01
Cs-137	1	5.9E-01	2.8E-05	1.31E-03	4.7E-06	4.71E-06	5.09E-04	3.7E-02
Tc-99	0.3	4.2E-01	4.7E-06	7.14E-03	4.7E-06	4.71E-06	9.42E-03	1.7E-01
Pu-241	350***	2.9E-02	All less than 4.71E-06		4.7E-06	4.71E-06	9.42E-03	1.7E-01
U-238	**	6.1E-03	5.4E-04	5.59E-04	4.7E-06	4.71E-06	8.05E-04	7.5E-03

* For activated metals, the Limit is 8.0 Ci/m³.

** No limits specified under 10 CFR 61.55.

*** Units are in nCi/g.

Table 5 Industrial Waste Volume and Activity Levels by Compact Regions and States - Aggregate Practices from 1986 to 1990^(a)

<u>Compact/State</u>	<u>Volume Vol. (m³)</u>	<u>Percent</u>	<u>Activity Act. (Ci)</u>	<u>Percent</u>
Northwest	12,800	18.0	553	0.2
Rocky Mountain	298	0.4	3,400	1.0
Central	5,980	8.4	54	<0.1
Midwest	4,480	6.3	5,590	1.7
Central Midwest	2,700	3.8	171	<0.1
Southeast	23,300	32.8	3,320	1.0
Northeast	3,770	5.3	27,700	8.6
Appalachian	4,990	7.0	23,600	7.3
Southwest	5,360	7.5	90,300	27.9
District of Columbia	16	<0.1	24	<0.1
Maine	14	<0.1	1	<0.1
Massachusetts	4,610	6.5	132,000	40.8
New Hampshire	80	<0.1	3	<0.1
New York	1,890	2.6	23,700	7.3
Rhode Island	4	<0.1	24	<0.1
Texas	892	1.2	13,300	4.1
Vermont	0.1	<0.1	0.2	<0.1
Total	71,184	--	323,740	--

(a) Data extracted from database. Waste volumes and activity levels are rounded off. Percentages may not add up to 100% because of rounding off. Puerto Rico did not dispose of any waste during the given period. To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

Figure 11. Industrial Waste Volume: 1986 to 1990

Figure 12. Industrial Waste Activity: 1986 to 1990

Few generalizations can be made about the distributions of radionuclide concentrations, except that the concentrations of individual radionuclides span several orders of magnitude and there is little pattern apparent in the distributions. As before, the 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, yielding a concentration of $4.7\text{E-}06 \text{ Ci/m}^3$ for a 55-gallon drum.

2.2.4.2 Waste Characterization - Shipment-Level

A search of the database, performed at the shipment-level, captured the following data for all direct shipments of Class A waste by all industrial waste generators from 1986 to 1990:

- 5,029 shipping manifests
- 55,130 cubic meters of waste
- $5.64\text{E+}07$ kg of waste, 1.02 g/cm^3 average density
- $1.05\text{E+}05$ Ci of total activity, 1.9 Ci/m^3

The results of this search represent about 72 percent of the volume and 29 percent of the activity of the waste shipped for disposal. The balance was shipped by brokers and processors and includes some Class B and C waste. In addition, the average gross radionuclide concentration in the sort is about 1.9 Ci/m^3 , while the average gross radionuclide concentration in all industrial waste is about 4.8 Ci/m^3 .

The results also reveal that average concentrations at the container-level are higher than at the shipment-level, which raises a question as to the representativeness of the container-level data. The results imply that one or more shipments were characterized by higher activity waste. As this is a "shipment-level" analysis, it is not possible to identify the corresponding waste streams and nuclides. The search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	10CFR61 Class A Limits	Total Activity Captured (Ci)	Concentration (Ci/m^3) Median	Average	1%ile or min.	10%ile	90%ile	99%ile or max.
C-14	0.8*	$3.7\text{E+}02$	$5.4\text{E-}04$	$1.7\text{E-}02$	$1.2\text{E-}06$	$1.1\text{E-}05$	$2.9\text{E-}02$	$2.4\text{E-}01$
Co-57	700	$6.3\text{E+}00$	$1.3\text{E-}03$	$4.7\text{E-}03$	$4.0\text{E-}08$	$1.9\text{E-}06$	$9.3\text{E-}03$	$5.3\text{E-}02$
Co-60	700	$1.3\text{E+}04$	$5.1\text{E-}03$	$1.5\text{E+}01$	$7.7\text{E-}08$	$1.7\text{E-}05$	$6.4\text{E+}00$	$4.5\text{E+}02$
H-3	40	$8.5\text{E+}04$	$3.5\text{E-}03$	$9.5\text{E-}01$	$2.4\text{E-}06$	$1.2\text{E-}04$	$4.9\text{E-}02$	$4.9\text{E+}00$
I-125	700	$8.0\text{E+}01$	$6.4\text{E-}03$	$3.7\text{E-}02$	$2.4\text{E-}06$	$6.3\text{E-}05$	$8.9\text{E-}02$	$4.0\text{E-}01$
Pu-241	350**	$5.1\text{E+}00$	$8.5\text{E-}06$	$2.2\text{E-}04$	$7.0\text{E-}07$	$4.7\text{E-}06$	$8.0\text{E-}04$	$9.2\text{E-}04$
Ra-226	***	$7.9\text{E+}00$	$3.9\text{E-}04$	$3.8\text{E-}04$	$4.4\text{E-}08$	$2.2\text{E-}06$	$5.5\text{E-}04$	$1.0\text{E-}03$
Tc-99	0.3	$2.4\text{E+}00$	$9.8\text{E-}05$	$6.5\text{E-}04$	$3.6\text{E-}08$	$1.2\text{E-}06$	$2.1\text{E-}03$	$5.4\text{E-}03$
U-238	***	$1.4\text{E+}03$	$2.7\text{E-}02$	$9.7\text{E-}02$	$3.7\text{E-}06$	$4.8\text{E-}05$	$3.9\text{E-}01$	$8.8\text{E-}01$

* For activated metals, the limit is 8.0 Ci/m^3 .

** Units are in nCi/g.

*** No limits specified under 10 CFR 61.55.

2.2.4.3 Locations of Waste Generators

The locations of the major industrial waste generators are identified by city, county, and state in Appendix G-1.

2.2.5 Medical Waste Generators

Medical waste generators are those designated as "medical" on the shipping manifests. However, to varying degrees, most categories of waste generators participate in practices that may be considered biomedical.

Low-level radioactive waste produced by medical facilities are associated with the use of radioactive materials in the practice of nuclear medicine, medical research, and clinical tests.

The biomedical waste streams reported most frequently by the various medical waste generators include:

- compacted trash
- laboratory
- biological
- animal carcasses
- absorbed liquids

This breakdown is based on the waste streams and forms most often cited by the three commercial low-level waste disposal sites. The most frequently reported biomedical radionuclides include Cr-51, H-3, I-125, S-35, C-14, Co-57, Fe-59, P-32, and U-238.

Waste volumes and activity levels shipped for disposal by medical waste generators and all waste generators are shown in Table 6 and Figures 13 and 14.

2.2.5.1 Waste Characterization - Container-Level

A search of the database, conducted at the container-level, captured the following data for all direct shipments of Class A waste and all medical waste generators from 1988 to 1990:

- 1 shipping manifest
- 109 container records
- 23 cubic meters of waste
- 17,120 kg of waste, 0.74 g/cm³ average density
- 3.3 Ci of total activity, 0.14 Ci/m³

The results of this search represent about one percent of the total waste volume and one percent of the activity shipped by medical waste generators. More importantly, the sort captured only one shipping manifest. The percentage captured is small because medical waste generators often use brokers and processors

Table 6 Medical Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 - 1990^(a)

<u>Compact/State</u>	<u>Volume Vol. (m³)</u>	<u>Percent</u>	<u>Activity Act. (Ci)</u>	<u>Percent</u>
Northwest	103	2.6	2.2	0.65
Rocky Mountain	10	0.25	0.66	0.20
Central	9.0	0.23	2.6	0.77
Midwest	438	11.0	76.9	22.6
Central Midwest	177	4.4	7.4	2.2
Southeast	59.1	1.5	4.5	1.3
Northeast	461	11.6	22.8	6.2
Appalachian	360	9.0	15.6	4.6
Southwest	805	20.2	136	40.0
District of Columbia	25.8	0.6	0.87	0.26
Maine	0.21	<0.1	0.36	0.11
Massachusetts	130	3.3	15.2	4.5
New Hampshire	0.15	<0.1	0.25	<0.1
New York	1,240	31.2	46.7	13.7
Puerto Rico	0	--	0.0	--
Rhode Island	116	2.9	2.2	0.65
Texas	45.1	1.1	5.8	1.7
Vermont	0.5	<0.1	0.011	<0.1
Totals:	3,980	--	340	--

(a) Data extracted from database. Waste volumes and activity levels are rounded off. Percent may not add up to 100% because of rounding off. Puerto Rico did not dispose of any waste during the given period. To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

Figure 13. Medical Waste Volume: 1986 to 1990

Figure 14. Medical Waste Activity: 1986 to 1990

and rarely ship waste directly to waste disposal facilities. Accordingly, the data captured in this sort may not be representative of the medical sector.

The search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	Class A Limits	Activity Shipped (Ci)	Concentration (Ci/m ³)		1%ile	10%ile	90%ile	99%ile
			Median	Average				
H-3	40	1.2E+00	1.2E-02	7.53E-02	1.4E-05	1.88E-04	1.41E-01	1.6E+00
I-125	700	8.7E-01	1.6E-03	4.46E-02	9.4E-06	1.41E-05	1.01E-01	1.4E+00
Cr-51	700	8.1E-01	2.8E-03	4.72E-02	4.7E-06	9.42E-06	2.01E-01	4.4E-01
S-35	700	2.7E-01	5.8E-03	2.79E-02	4.7E-06	2.35E-05	7.49E-02	2.4E-01
P-32	700	9.2E-02	1.4E-03	9.37E-03	4.7E-06	9.42E-06	3.49E-02	6.9E-02
C-14	0.8	2.0E-02	9.4E-05	2.62E-03	4.7E-06	2.35E-05	4.28E-03	5.7E-02
Ca-45	700	1.3E-02	1.2E-03	1.65E-03	4.7E-05	1.18E-04	4.08E-03	5.8E-03
Co-57	700	3.3E-03	1.4E-05	4.81E-04	4.7E-06	4.71E-06	7.06E-05	1.4E-02
Fe-59	700	1.2E-04	8.0E-05	1.13E-04	4.7E-06	4.71E-06	3.53E-04	3.53-04

Few generalizations can be made about the distributions of the radionuclide concentrations, except that the 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, which yields a concentration of 4.7E-06 Ci/m³ for 55-gallon drum.

2.2.5.2 Waste Characterization - Shipment-Level

A search of the database, performed at the shipment-level, captured the following data for all direct shipments of Class A waste by all medical waste generators from 1986 to 1990:

- 1,032 shipping manifests
- 1,256 cubic meters of waste
- 9.73E+05 kg of waste, 0.78 g/cm³ average density
- 50.3 Ci of total activity, 0.04 Ci/m³

The results of this search represent about 34 percent of the volume and 14 percent of the activity of the waste shipped for disposal by medical waste generators. The balance was shipped by brokers and a very small portion may contain Class B and C waste. In addition, the average gross radionuclide concentration in the sort is about 0.04 Ci/m³, while the average gross radionuclide concentration in all medical waste is about 0.1 Ci/m³. These radionuclide concentration results are not consistent with the results of the container-level analysis presented above, which has an average concentration of 0.14 Ci/m³. This difference may be due, in part, to the nonrepresentative nature of the container-level data since the sort captured only one shipping manifest.

The search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	10CFR61 Class A Limits (Ci/m ³)	Total Activity Captured (Ci)	Concentration (Ci/m ³)		1%ile or min.	10%ile	90%ile	99%ile or max.
			Median	Average				
I-125	700	2.0E+01	2.0E-03	1.4E-02	4.7E-06	2.2E-04	2.3E-02	3.0E-01
H-3	40	1.1E+01	2.2E-03	1.1E-02	1.6E-06	1.4E-05	3.2E-02	1.1E-01
Cr-51	700	4.6E+00	3.2E-03	7.6E-03	9.4E-07	2.4E-05	2.1E-02	4.2E-02
P-32	700	4.4E+00	3.7E-03	1.3E-02	7.9E-07	1.2E-04	2.8E-02	1.6E-01
S-35	700	4.3E+00	1.7E-03	7.1E-03	9.4E-07	7.9E-05	2.2E-02	5.5E-02
C-14	0.8	1.1E+00	2.2E-04	1.1E-03	1.2E-06	1.3E-05	3.1E-03	9.6E-03
Co-57	700	3.3E-01	4.0E-05	3.4E-04	1.6E-06	6.6E-06	4.8E-04	3.5E-03
Ca-45	700	1.1E-01	9.8E-05	4.0E-04	1.2E-06	3.9E-06	4.7E-04	5.9E-03
Fe-59	700	4.6E-02	1.5E-04	9.3E-04	2.3E-06	1.3E-05	2.2E-03	9.9E-03

2.2.5.3 Locations of Waste Generators

The locations of the major medical waste generators are identified by city, county, and state in Appendix G-1.

2.2.6 Nuclear Power Plants

The radioactivity found in power plant waste streams is primarily due to neutron-activated corrosion products circulating in the primary coolant. Another source of radioactivity is associated with the leakage of mixed fission products from fuel elements into the coolant system. The resulting radioactivity plates-out in plant components and accumulates in systems designed to purify the primary cooling system. Low-level waste is generated when plant components are opened for maintenance or replaced and when filtration and purification systems are cleaned. Waste is also generated during major plant outage activities, e.g., refueling, steam generator or condenser tube repairs, and chemical decontamination.

Various waste streams are generated during plant operation and maintenance. Routine operations result in the generation of wet waste, while major plant outages yield relatively more dry active and dry solid waste. The generation of dry waste streams is usually associated with maintenance activities that involve a large work force, require access into all plant areas, and include accessing contaminated plant systems and components. Wet waste streams include spent resins, sludge, filters, and evaporator bottoms.

In general, nuclear power plant waste can be segregated into five major categories: dry active, dry solids and equipment, wet waste forms and liquids, gaseous effluent treatment system filtration media, and unusual waste forms.

Utilities also occasionally use radioactive materials obtained from outside sources, e.g., radio-chemical laboratories and sealed source manufacturers. Such radioactive materials are used in laboratory applications, non-destructive testing, and for calibrating radiation monitoring equipment. However, the amount of radioactivity used in such applications is small compared to the amount contained in waste associated with plant operations.

About 20 radionuclides make up nearly 99 percent of the radioactivity produced by power plants. The following radionuclides are typically shipped as Class A waste: Cr-51, Mn-54, H-3, C-14, Co-58, Zn-65, Cs-137, Fe-59, Ag-110m, Fe-55, Zr-95, Ce-144, Co-60, Nb-95, Ni-63, Ru-103, Ru-106, Sb-124, Cs-134.

Table 7 and Figures 15 and 16 present the volumes and activity levels of waste shipped by nuclear power plants by Compact regions and unaffiliated States.

2.2.6.1 Waste Characterization - Container-Level

A search of the database, conducted at the container-level, captured the following data for all direct shipments of Class A waste by all nuclear power plants in 1989:

- 437 shipping manifests
- 8,199 container records
- 4,114 cubic meters of waste
- $3.81\text{E}+6$ kg of waste, 0.93 g/cm^3 average density
- 5,605 Ci of total activity, 1.36 Ci/m^3

The results of this search represent about 17 percent of the total waste volume and 0.8 percent of that shipped by all nuclear utility waste generators in 1989.

The percentage of the activity captured in the sort is much smaller than the percentage of the volume because most of the activity in low-level waste is contained in Class B and C waste, which comprises about 5 percent of the volume. For the same reason, the average gross radionuclide concentration is about 1.36 Ci/m^3 , while the average gross radionuclide concentration in all utility waste is about 30 Ci/m^3 .

Table 7 Utility Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 to 1990^(a)

<u>Compact/State</u>	<u>Volume Vol. (m³)</u>	<u>Percent</u>	<u>Activity Act. (Ci)</u>	<u>Percent</u>
Northwest	2,910	2.4	7,490	0.4
Rocky Mountain	56	<0.1	1,180	<0.1
Central	6,100	5.1	12,200	0.7
Midwest	10,900	9.1	215,000	12.6
Central Midwest	17,300	14.5	236,000	13.9
Southeast	35,800	30.0	192,000	11.3
Northeast	10,800	9.1	746,500	43.9
Appalachian	16,400	13.8	134,000	7.9
Southwest	7,140	6.0	14,100	0.8
Maine	668	0.6	1,290	<0.1
Massachusetts	2,570	2.2	10,600	0.6
New York	7,710	6.5	118,000	6.9
Texas	107	0.1	21	<0.1
Vermont	747	0.6	12,700	0.8
Total	1.2E+5	--	1.7E+6	--

(a) Extracted from LLW database. Includes all Class A, B, and C waste. Waste volumes and activity levels are rounded off. Percentages may not add up to 100% because of rounding. Puerto Rico, Rhode Island, New Hampshire, and the District of Columbia did not dispose of any waste during the given period. To convert volume to cubic feet, multiply cubic meter by 35.3. To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq.

Figure 15. Utility Waste Volume: 1986 to 1990

Figure 16. Utility Waste Activity: 1986 to 1990

In summary, the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	Class A Limits (Ci/m ³)	Activity Shipped (Ci)	Concentration (Ci/m ³)		1xile	10xile	90xile	99xile
			Median	Average				
Fe-55	700	2.5E+03	7.0E-03	5.71E-01	4.7E-06	2.17E-04	2.44E+00	5.7E+00
Co-60	700	1.3E+03	2.8E-03	1.99E-01	4.7E-06	1.08E-04	7.96E-01	2.5E+00
Mn-54	700	4.5E+02	1.1E-03	8.38E-02	4.7E-06	1.88E-05	3.67E-01	7.6E-01
Co-58	700	1.2E+02	1.6E-03	1.46E-02	4.7E-06	9.42E-05	3.92E-02	1.1E-01
Ni-63	3.5*	6.0E+01	1.0E-03	9.21E-03	4.7E-06	8.95E-05	1.77E-02	9.7E-02
Cs-137	1	5.2E+01	1.5E-03	1.04E-02	4.7E-06	9.42E-06	1.53E-02	2.1E-01
H-3	40	3.4E+01	8.9E-04	4.07E-03	4.7E-06	4.71E-06	9.28E-03	8.1E-02
C-14	0.8**	7.4E+00	4.7E-06	1.23E-03	4.7E-06	4.71E-06	8.99E-04	1.9E-02
Tc-99	0.3	5.1E-01	4.7E-06	3.39E-04	4.7E-06	4.71E-06	6.36E-04	7.6E-03
I-129	0.008	2.6E-02	4.7E-06	1.76E-05	4.7E-06	4.71E-06	4.71E-06	9.9E-05

* In activated metals, the limit is 35 Ci/m³.

** In activated metals, the limit is 8.0 Ci/m³.

In addition to the above generalizations, the 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, resulting in a concentration of 4.7E-06 Ci/m³ for a 55-gallon drum.

2.2.6.2 Waste Characterization - Shipment-Level

A search of the database, performed at the shipment-level, captured the following data for all direct shipments of Class A waste by all nuclear power plants in 1989:

- 868 shipping manifests
- 8,125 cubic meters of waste
- 7.72E+06 kg of waste, 0.95 g/cm³ average density
- 7,493 Ci of total activity, 0.92 Ci/m³

The results of this search represent about 34 percent of the volume and 1.0 percent of the activity of the waste shipped for disposal by all nuclear power plants. The balance, 66 percent, was shipped by brokers and processors and contains some Class B and C waste. In addition, the average gross radionuclide concentration in the sort is about 0.92 Ci/m³, while the average gross radionuclide concentration in all utility waste is about 30.3 Ci/m³. The percentage of activity captured is small relative to the total activity shipped because the sort does not include Class B and C waste, which contains most of the radioactivity.

The shipment-level radionuclide concentration results are comparable to those obtained at the container-level. Accordingly, the container-level data appear to be representative of utility waste. The search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	10CFR61 Class A Limits	Total Activity Captured (Ci)	Concentration (Ci/m ³)		1%ile or min.	10%ile	90%ile	99%ile or max.
			Median	Average				
C-14	0.8*	2.9E+01	4.9E-04	8.8E-03	1.8E-06	4.6E-05	1.4E-02	1.5E-01
Co-58	700	4.0E+02	1.8E-02	1.3E-01	4.2E-07	8.8E-04	1.6E-01	1.3E+00
Co-60	700	1.9E+03	8.6E-02	6.1E-01	1.2E-05	3.9E-03	1.6E+00	6.4E+00
Fe-55	700	2.5E+03	6.2E-02	9.6E-01	6.6E-06	3.0E-03	2.8E+00	1.4E+01
H-3	40	7.6E+01	1.2E-03	1.6E-02	4.3E-06	2.5E-04	3.6E-02	1.7E-01
I-129	0.008	1.2E-01	4.7E-06	4.7E-05	1.3E-07	2.8E-07	1.5E-04	8.2E-04
Mn-54	700	5.8E+02	4.1E-02	2.2E-01	2.1E-06	1.3E-03	5.7E-01	2.8E+00
Ni-63	3 E**	2.7E+02	8.7E-03	7.2E-02	1.3E-05	5.6E-04	7.0E-02	1.8E+00
Tc-99	0.3	7.5E-01	5.9E-06	1.7E-04	1.8E-07	6.0E-07	1.7E-04	3.5E-03

* In activated metals, the limit is 8.0 Ci/m³.

** In activated metals, the limit is 35 Ci/m³.

2.2.6.3 Locations of Waste Generators

The regions with the greater number of power plants include the Southeast Compact, the Midwest Compact, the Central Midwest Compact, and the Appalachian Compact. Table 7-1 (in Section 7.0, Volume 2) presents the location of all operating nuclear power plants in the United States. Additional information is provided in Appendix G-1.

2.2.7 Waste Brokers and Processors

It is common practice for waste generators to secure commercial services for their disposal needs. Waste brokers take care of manifesting each shipment and arrange for waste transportation and disposal. Some waste brokers or processors also provide other types of services, such as waste processing and treatment, consolidation, and decontamination and decommissioning.

A detailed container and shipment-level analysis of the database for brokered waste was not performed because brokers and processors are generally not major waste generators. Virtually all of the waste handled by brokers and processors originates from the five categories of waste generators discussed in the preceding sections. Because of the inherent limitations of the database, it is not possible to conduct detailed analyses of brokered waste shipments. This is unfortunate, since brokers handle a large portion of the nation's low-level waste. This limitation may be circumvented by obtaining specific shipping manifest data directly from the disposal sites.

Waste volumes shipped by brokers to each disposal site are shown in Tables 8 and 9. The results summarize aggregate practices from 1986 to 1990 of all brokered shipments, for Class A waste (stable and unstable) only, all waste generators, and all regions. The results reveal that the majority of the waste volume and activity is shipped directly by the waste generators.

Table 8 Waste Volume and Activity Levels Shipped by Brokers and Processors - Aggregate Practices for All Class A Waste from 1986 to 1990^(a)

<u>Parameter</u>	<u>Barnwell</u>	<u>Richland</u>	<u>Beatty</u>	<u>Total</u>
Number of shipping records:	1,787	794	293	2,874
Records with container data				
No. of records:	na	494	192	686
No. of containers:	na	34,914	11,075	45,989
Activity (Ci):	4.22E+04	1.75E+04	1.86E+04	7.8E+4
% of total:	2.0	0.8	0.9	3.9
Volume ^(b) (m ³):	2.83E+04	1.36E+04	4.64E+03	4.7E+4
% of total:	13.2	6.4	2.2	22
Total weight ^(b) (kg):	2.83E+07	1.36E+07	4.64E+06	---
Average or assumed ^(c) waste density (g/cm ³):	1.0	0.79	1.08	---
Yearly Averages				
Activity (Ci):	8.44E+03	3.50E+03	3.72E+03	---
Volume (m ³):	5.66E+03	2.72E+03	9.28E+02	---
Weight (kg):	5.67E+06	2.72E+06	9.28E+05	---

- (a) Totals are for all brokered shipments, Class A waste (stable and unstable), all waste generators, and all Compacts and States from 1986 to late 1990.
- (b) Total weights are based on a nominal density of 1.0 g/cm³ since not all shipments and containers have weight data. Volumes and weights include the overall container volume and mass and not the net waste volume or mass.
- (c) Except for Barnwell, average waste densities reflect only shipments with container data.

Table 9 Institutional, Utility, and Industrial Generators
Usage Pattern of Waste Brokers from 1986 to 1990^(a)

<u>Compact/State</u>	Waste Volume and Activity Distribution (%)					
	<u>Government</u>		<u>Academic</u>		<u>Medical</u>	
	<u>Vol.</u>	<u>Act.</u>	<u>Vol.</u>	<u>Act.</u>	<u>Vol.</u>	<u>Act.</u>
Northwest	0.8	37.7	23.2	32.4	62.3	53.2
Rocky Mountain	100	100	76.9	99.7	100	100
Central	76.8	100	94.3	99.2	100	100
Midwest	3.0	98.0	94.6	71.1	64.1	82.8
Central Midwest	70.9	69.7	91.2	97.7	99.0	100
Southeast	3.5	97.0	25.1	94.3	68.5	82.2
Northeast	42.2	77.4	41.8	76.5	71.5	57.3
Appalachian	7.6	94.3	85.4	88.5	65.9	80.9
Southwest	9.3	99.4	74.6	84.6	69.8	93.0
District of Columbia	100	100	67.1	20.3	91.8	99.4
Maine	21.1	85.6	1.9	10.9	100	100
Massachusetts	6.1	94.3	74.5	46.1	73.6	96.8
New Hampshire	100	100	63.7	100	100	100
New York	86.2	37.1	85.6	39.4	60.0	73.9
Puerto Rico ^(b)	---	---	---	---	---	---
Rhode Island	9.1	100	68.1	15.2	89.5	71.9
Texas	2.9	97.8	100	100	100	100
Vermont	0.0	0.0	46.7	33.4	14.3	0.0

(a) Percentages are based on total waste activity and volumes reported by the disposal sites. Data extracted from the database (see Section 8, Volume 2 for details).

(b) No waste were disposed of during for the reported period.

Table 9 Institutional, Utility, and Industrial Generators
Usage Pattern of Waste Brokers from 1986 to
1990^(a), Cont'd

<u>Compact/State</u>	Waste Volume and Activity Distribution (%)			
	<u>Utility</u>		<u>Industrial</u>	
	<u>Volume</u>	<u>Activity</u>	<u>Volume</u>	<u>Activity</u>
Northwest	7.9	0.1	2.2	47.0
Rocky Mountain	43.1	0.1	81.6	100
Central	11.6	0.4	3.1	0.4
Midwest	16.0	0.1	17.6	64.9
Central Midwest	19.1	0.1	29.6	91.8
Southeast	21.8	9.6	23.6	12.6
Northeast	13.7	<0.1	56.5	1.5
Appalachian	19.3	0.7	38.2	91.1
Southwest	6.5	5.2	39.7	14.7
District of Columbia	-- na --		78.2	32.1
Maine	34.3	1.0	41.9	64.4
Massachusetts	23.0	0.1	19.4	0.2
New Hampshire	- no data -		8.4	3.7
New York	23.1	0.1	25.5	0.9
Puerto Rico ^(b)	-- na --		---	---
Rhode Island	-- na --		47.4	62.0
Texas	61.8	3.0	26.4	9.1
Vermont	2.2	<0.1	0.0	0.0

(a) Percentages are based on total waste activity and volumes reported by the disposal sites. Data extracted from the database (see Section 8, Volume 2 for details).

(b) No waste were disposed of during the reported period.

Specifically, brokered shipments constituted about 22 percent of the volume and four percent of the activity from 1986 to 1990.

Table 9 presents the percentage of the total waste volume and activity shipped by brokers from 1986 to 1990 by Compact or unaffiliated State and category of waste generators. This sort was conducted by identifying all brokered waste shipments and summing total waste volumes and activity levels. This sort does not differentiate waste volumes by category of generators. Institutional and industrial waste generators tend to make greater use of brokers than does the utility sector. Waste volumes and amounts of activity handled through brokers also vary by region, from minimal amounts (<0.1 percent) to all (100 percent) of that produced by a Compact or State.

Notwithstanding the preceding information, there still is a great deal of uncertainty about waste volumes handled by processing facilities, although various organizations have conducted studies and surveys (OTA89, DOE90, CDH89, IDN90, NRC86, NRC85, NUM90). In its 1989 report, the Congressional Office of Technology Assessment, after reviewing past studies, concluded that some of the uncertainties were due to the reluctance or inability of the generators to identify waste streams, data misinterpretation in reviewing overlapping survey results, and the use of inconsistent survey questionnaires (OTA89).

A series of container-level sorts indicates that the distribution of radionuclides in brokered waste is not observably different than that observed in direct shipments.

The locations of some of the major waste brokers and processors are identified by city, county, and state in Appendix G-3. This listing does not constitute an endorsement of such firms.

3.0 TREATMENT AND DISPOSAL PRACTICES FOR WASTE REGULATED UNDER THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) SUBPARTS C AND D

This report provides a collection of databases characterizing the methods and facilities being used to treat and dispose non-radioactive waste, including industrial, municipal, and hazardous wastes regulated under Subparts C and D of the Resource Conservation and Recovery Act (RCRA).

3.1 Technical Approach and Methods

The database was compiled from the results of surveys performed by the EPA, published literature, EPA contractor reports, and available databases. The principal sources of information are cited in each of the sections that follow. Appendix P is an index identifying where to find the geographic location of treatment and disposal facilities within this report.

3.2 Results - Characterization of Methods and Facilities to Treat and Dispose of Non-Radioactive Waste Under Subparts C and D of RCRA

3.2.1 Waste Treatment

In this summary, "treatment technologies" refers to techniques for treating or processing wastes prior to final disposal. The treatment techniques that have widespread use include recycling and incineration.

3.2.1.1 Recycling

The Environmental Protection Agency is placing a strong emphasis on recycling as many materials as possible. The impetus for this effort comes from the Resource Conservation and Recovery Act (RCRA) and from the rapid nationwide depletion of landfill capacity.

Most recycling programs operate today at the local level as part of either city or county programs. As landfill space has dwindled and dumping costs have risen, many states have moved to encourage or mandate municipal solid waste recycling through legislation. State recycling initiatives include laws that require communities, counties, or regions to develop recycling programs, bottle bill container laws, and measures that encourage but do not mandate recycling. Chapter 9 of Volume 3 of this report lists current recycling legislation and policies in selected states.

Currently, 11 states have some type of mandatory municipal solid waste recycling legislation. The number of curbside collection programs has increased to between 3,000 to 3,600 programs, a nine-fold increase since 1986. More than 40 states have some form of legislated recycling goal. Most of these require or encourage some type of community curbside or drop-off recycling (GER92).

In addition to legislation, industry or non-profit recycling collection networks exist in most states. These operations vary in sponsor, size, and materials collected. In many states, programs include established drop-off centers and promotion campaigns which could act as foundations for statewide collection programs.

It is estimated that more than 600 curbside collection programs are currently operating in communities across the country. Pilot programs to discover the most effective means of collecting the most recyclable material are now common.

Chapter 9 of Volume 3 provides information on the participation rates, collection quantities, and the program specifics from 22 municipal curbside collection programs. Participation rates of 85 to 98 percent are typical for mandatory programs. Newspapers, glass, aluminum, and plastics are the most common materials collected.

In addition to curbside collection for recycling, separation and recycling of materials can take place at the municipal combustor or landfill. About 40 percent of the existing combustion facilities have on-site recovery facilities. This percentage drops to 30 percent if incinerators that do not recover energy are included. Of these facilities, 85 percent recover ferrous metals, 27 percent recover non-ferrous metals, and a few recover glass and plastic.

3.2.1.2 Incineration

Combustion, with or without energy recovery, is becoming a more common method of municipal waste reduction. EPA has set a goal of increasing the proportion of municipal solid waste incinerated from 9 percent in 1989 to 20 percent in 1992 (EPA89).

In this report, three variations for the combustion of wastes are examined:

- On-site incineration as a nonhazardous waste in a small combustor (such as a hospital or biomedical research facility would have for the disposal of infectious waste).
- Off-site incineration as a nonhazardous waste in a municipal waste combustor.
- Off-site incineration as a hazardous waste at a permitted Subtitle C facility.

On-site Incineration

In on-site incineration, waste are collected, stored, and incinerated on site. The resulting ash (if not hazardous) is collected and hauled to a municipal waste landfill for disposal. If hazardous, the waste is sent to a Subtitle C (hazardous) disposal facility. Because on-site incineration is often used by the bio-medical sector, information for this technology is drawn from the data gathered on hospital incinerators.

Facilities that handle biomedical waste, such as hospitals, research facilities, and manufacturers, are also likely to handle infectious waste. Many states require incineration for the disposal of infectious wastes (EPA88a and Appendix L of this report). In March 1990, there were approximately 5,500 hospitals in the United States¹, and over 90 percent of these facilities operate incinerator equipment of some kind (EPA88a).

Many of the units are small and are not subject to standards of performance or emission guidelines promulgated under the provisions of the Clean Air Act (EPA88a). Units combusting solely medical waste are not covered by standards of performance for combustors (40 CFR 60.50a(g)) or emission guidelines for existing facilities (40 CFR 60.30.a(f)).

Many units do not have heat input capacities above 100 million BTU/hr or a design capacity above 50 tons/day. Therefore, they are not subject to NSPS for institutional boilers (40 CFR 60.40b) or guidelines for the thermal processing of solid waste (40 CFR 420).

Table 10 presents the design and site characteristics of on-site incinerators based on a survey of 433 hospital incinerators in New York (EPA88a).

Off-site Municipal Incinerators

In off-site incineration, the combustible waste is separated at the point of generation. The material is collected at the generating site along with other trash and transported by truck to the incineration site. The resultant ash (if not hazardous) is either transported to a landfill or is disposed of at an on-site landfill.

A 1990 survey indicates that there are currently 168 municipal waste combustion (MWC) facilities in operation in the United States (KIS90).

¹ Bezub, Milton, American Hospital Association, Washington, D.C., personal communication with Maureen F. Kaplan, Eastern Research Group, Inc., Arlington, MA, 27 November, 1990, regarding hospitals with incinerators.

Table 10 Design and Site Characteristics of On-site Incinerators^(a)

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Feed Rate (lbs/hr)	150	1	2,700
Stack Height (ft)	78	6	365
(m)	24	2	111
Nearest Exposed Member of Population	10 meters		
Population Density (50-Mile Radius)	Up to 68,015 persons/mi ² in NYC		
Operating Duration	5 days/week 4 hours/day		
Operating Cycle			
Ash clean-out	15 - 30 min.		
Preheat	15 - 60 min.		
Waste loading	5 - 6 hours		
Burndown	2 - 4 hours		
Cooldown	5 - 8 hours		
Volume Reduction Factor	90%		
Mass Reduction Factor	3		
Waste Transport Distance	Not Applicable		

(a) Extracted from EPA88a.

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

Only 40 of these are incinerators, while the remaining 128 are waste-to-energy (WTE) plants. Not included in the count are 12 refuse-derived fuel (RDF) processing facilities that generate a prepared fuel for off-site combustion. An additional 19 WTE plants are under construction, and 79 MWC plants are in the planning stage (active and inactive). From 1986 to 1989, the WTE capacity in the United States nearly doubled, and the figure could double again by the mid-1990s if all projects under construction and in final planning stages come on line (LEG89).

Table 11 presents the design and site characteristics of municipal incinerators based on a 1990 national survey (KIS90).

Off-site Hazardous Waste Incinerator

For hazardous waste, the combustible waste is separated at the point of generation. The material is collected at the generating site and transported to the incineration site. If the combusted waste is a listed hazardous waste, the ash is sent to a hazardous waste landfill. If the waste is a characteristic hazardous waste, the ash is tested. The results of the tests determine whether the ash is sent to a Subtitle D (nonhazardous) or Subtitle C (hazardous) facility for disposal.

A waste is considered hazardous if it is listed as a hazardous waste or it exhibits one or more of the following characteristics:

- ignitability
- corrosivity
- reactivity
- toxicity

The last parameter is measured by the toxicity characteristic leaching procedure (TCLP; EPA90). The EPA has already determined that some specific wastes are hazardous, and these are referred to as "listed" waste (CFR89a). Toluene, for example, is a component of some scintillation fluids. The presence of toluene in a waste may cause it to exhibit the hazardous characteristic of toxicity. Only if toluene is discarded as part of a spent solvent or off-specification product would it be a listed hazardous waste.

The process for disposing of hazardous waste is very similar to that for the disposal of low-level radioactive waste. The generator must prepare a manifest which tracks the waste until

Table 11 Design and Site Characteristics of Municipal Incinerators^(a)

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Feed Rate (tons/day)	200	5	3,300
Stack Height (ft)	140	25	365
Mass Reduction Factor	3	2	13
Release Rate (gr/dscf)		0.08	
Personnel Requirements	16 (for 900 ton/day RDF facility)		
Operating Characteristics	10 person years/yr labor 3 person years/yr supv. 3 person years/yr maint. labor		
Nearest Exposed Member of Population	No data available		
Population Density (NE Site)	up to 32,167/mi ² (Brooklyn)		
Transportation Distance (Miles)	88	6	306

(a) Extracted from KIS90.

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

its ultimate disposal, and a licensed transporter is required to follow the Department of Transportation (DOT) and EPA regulations regarding the pick-up, transport, and delivery of hazardous waste to a licensed treatment or disposal facility. The DOT regulations may be found in 49 CFR 171-179. Treatment and disposal must occur in licensed facilities in accordance with established performance standards (CFR89b).

The data characterizing off-site hazardous waste incinerators were obtained from national surveys in which there were 238 respondents. A comprehensive description of the results of the surveys is provided in Section 10 of Volume 3. Table 12 summarizes the results of the surveys.

3.2.2 Disposal Technologies

This section discusses the final disposal of the waste. Waste forms that are solid, or have been solidified, and are not recyclable are permanently disposed of at landfills, are addressed.

Landfills fall into two general categories -- Subtitle D facilities that accept non-hazardous waste and Subtitle C facilities that accept hazardous waste. (The terms derive from the part of the Resource Conservation and Recovery Act (RCRA) in which they are discussed.) Subtitle D facilities include both industrial and municipal solid waste landfills (MSWLF) (EPA88b). Industrial landfills are usually located at the generating facility.

3.2.2.1 Subtitle D Facilities - Municipal Solid Waste Landfills

In 1985, EPA conducted a census of landfills which resulted in an estimate of 7,645 municipal landfills (EPA86). The geographic distribution of those landfills is illustrated in Figure 17. The 1985 census formed the basis of a survey conducted by EPA in 1986 (EPA87). The survey was not a census, but a stratified sample with the stratification based on sample size. There were 1,076 respondents, representing an estimated 6,034 facilities. Table 13 summarizes the results of the survey.

In 1991, EPA promulgated requirements for municipal solid waste landfills (EPA91a). New landfill units and lateral expansions will be required to have liners, a leachate collection system, a final cover, and a groundwater monitoring system. EPA published an updated list of landfills in 1992 (EPA92). This list is included as Appendix O.

Table 12 Design and Site Characteristics of Hazardous Waste Incinerators^(a)

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Feed Rate (tons/day)	4	0.7	144
Size (acres)	40	2	1,080
Stack Height (ft)	No information available		
Mass Reduction Factor	13	7	13
Personnel Requirements			
Haz. Waste Ops.	31	3	2,000
Support Ops.	48	1	257
Contractors	154	- ^(c)	4,600
Total	1,821	5	24,159
Nearest Property Line (feet) ^(c)	250	-	1,600
Nearest Individual (feet)	2,685	120	10,000
Population 50-Mile Radius	143,968	9,270	53 million
	(Sullivan Co, TN)	(Carroll Co, KY)	(Cook Co, IL)
Population within 1 mile	250	-	20,000
Transportation Distance (Miles)	250	63	800

(a) Extracted from RTI91a.

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

(c) No data cited or available.

Figure 17. 1985 Active Municipal Waste Landfill Sites
Source: EPA88b

Table 13 Design and Site Characteristics of Municipal Solid Waste Landfills^(a)

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Age of Facilities	19	-(c)	100
Anticipated Lifetime	40 (half the facilities will close by 1999)		
Size (acres)	40	1	5,250
Depth (yards)	4	-	331
Capacity (millions of cubic yards)	0.375	0.308	364
Waste:Cover Ratio	4:1, 3:1	1:1	10:1
Annual Volume (MT/yr)	49,540	5	6,259,680
Types of Waste and Packaging (% per state)			
Non container liq.	-(c)	-	50
Containerized liq.	-	-	50
Containerized other	-	-	20
Current Liner Types (%)		-- no data --	
Clay	46.1		
Soil	20.7		
Membrane	1.1		
Asphalt	0.1		
Other	6.6		
None/Unknown	39.7		
Planned Liner Types (%)		-- no data --	
Clay	50.4		
Soil	20.2		
Membrane	6.4		
Asphalt	0.1		
Other	8.0		
None/Unknown	34.5		

(a) Summary of the EPA survey results, see text (RTI90).

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

(c) No data cited or available.

Table 13 Design and Site Characteristics of Municipal
Solid Waste Landfills^(a), Cont'd

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Current Cover Type (%)		-- no data --	
Soil	49.8		
Sand or Gravel	14.2		
Re-compacted Clay	32.4		
Membrane	1.7		
Topsoil	37.3		
Other	5.2		
Unknown	6		
Planned Cover Type (%)		-- no data --	
Soil	49.5		
Sand or Gravel	10.4		
Re-compacted Clay	32.9		
Membrane	2.5		
Topsoil	37.3		
Other	10.2		
Unknown	4.3		
Landfill Method (%)		-- no data --	
Area	47		
Trench	68		
Both	41		
Unspecified	5		
Leachate Management (%)		-- no data --	
With Leachate Mgmnt.	11.5		
Recirculate	31.2		
Land Application	12.6		
To POTW or Sewer	38.4		
To Surface Water	13.5		
Other/offsite treat.	2.7		
Onsite treat.	21.2		
Hydrogeological Parameters			
Permeability (cm/sec)	0.74	1.0E-12	1
Porosity (%)	25.9	1.0E-02	90
Hydr. Gradient (%)	4.20	1.0E-02	60
Personnel	1 employee per 70 tons/day		

(a) Summary of the EPA survey results, see text (RTI90).

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

Table 13 Design and Site Characteristics of Municipal
Solid Waste Landfills^(a), Cont'd

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Distance to Receptors (ft)			
Private Well	1,850	2	>5,280
Public Well	2,357	220	>5,280
Surface Water	1,989	50	>5,280
Groundwater Speed (ft/yr)	16	0.01	73,000
Number Private Wells in 1 Mile	17	1	1,100
Population Served in 1 Mile by Private Wells	45	1	1,500
Number Public Wells in 1 Mile	2	1	17
Population Served in 1 Mile by Public Wells	3,639	2	55,000
No. Rivers/Streams within 1 Mile	1	1	2
Population Served by Rivers/Streams within 1 mile	14,350	2	250,000
Lakes/Reservoirs within 1 Mile	1	1	2
Population Served by Lakes/Reservoirs within 1 mile	11,445	2	150,000

(a) Summary of the EPA survey results, see text (RTI90).

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

Table 13 Design and Site Characteristics of Municipal
Solid Waste Landfills^(a), Cont'd

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Population Served by Nearest Water Source Within A Mile of the Site ^(c)			
Private Well	14	0	1,500
Public Well	4,098	0	55,000
River/Stream	12,518	0	250,000
Lake/Reservoir	11,748	2	150,000
Transportation Distance to Landfill Among States (miles)	24	8	93

(a) Summary of the EPA survey results, see text (RTI90).

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

(c) A zero entry indicates no water source within a mile of the site.

3.2.2.2 Subtitle C Facilities - Hazardous Waste Landfills

Hazardous waste is segregated at the point of generation for separate transport and disposal. Land disposal restrictions specify the form and concentration levels in waste sent to hazardous waste landfills. Many wastes require treatment such as incineration or neutralization prior to disposal in a Subtitle C landfill (EPA91b).

The process for disposing of hazardous waste is similar to that for the disposal of low-level radioactive waste. The generator must prepare a manifest which tracks the waste until its ultimate disposal, and a licensed transporter is required to follow the Department of Transportation (DOT) and EPA regulations regarding the pick-up, transport, and delivery of hazardous waste to a licensed treatment or disposal facility. Treatment and disposal must occur in EPA or state-licensed facilities. Performance standards for owners of hazardous waste landfills are found elsewhere (CFR89c).

The information for facility features and characteristics is drawn from two EPA surveys:

- National Survey of Hazardous Waste Treatment, Storage, Disposal and Recycling Facilities, OMB No. 2050-0070, expires June 1988
- National Survey of Hazardous Waste Generators, OMB No. 2050-0075, expires November 1989

The data were compiled by RTI, using the SAS format (RTI91b).

Responding to the survey were 130 facilities. A detailed description of the survey findings is provided in Section 10 of Volume 3. Table 14 summarizes the results of the survey.

Table 14 Design and Site Characteristics of Hazardous Waste Landfills^(a)

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Size (acres)			
Commercial	448	1	3,000
Depth (yds)	9.4	0.6	23.7
Quantity Waste			
Solid Waste (tons)			
Commercial	82,245	27	603,556
Private	8,234	1	142,224
Quantity Liquid			
Solid Waste (10 ⁶ gal)			
Commercial	23	5	38
Private	0.2	0.002	0.756
Capacity (yd ³)	8.6E+5	3.0E+3	8.4E+6
Liners (% with liners)		-- no data --	
Single	19		
Top and Bottom	28		
Unspecified	25		
Covers (% with covers)		-- no data --	
Synthetic	84		
Earthen	59		
Other	31		
Geohydrology		-- no data --	
In Karst Terrain (#)	-(c)		
In Wetland (#)	-		
Above High			
Water Table (#)	14		
Depth to Aquifer (ft)	49	3	250
Permeability (cm/sec)	0.0012	6.0E-8	0.013
Porosity (%)	27.3	10	45
Hydr. Gradient (%)	2.47	0.02	25
Horiz .Flow (ft/yr)	11.38	-	58
Population Within			
1 Mile	481	-	4,000

(a) Extracted from RTI91b, see text for details.

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

(c) No data cited or available.

Table 14 Design and Site Characteristics of Hazardous Waste Landfills^(a), Cont'd

<u>Parameter</u>	<u>Typical</u> ^(b)	<u>Minimum</u>	<u>Maximum</u>
Water Bodies Within 1 Mile (% facilities)		-- no data --	
Private Well	21		
Public Well	4		
River/Stream	65		
Lake/Reservoir	21		
Distance to Nearest (feet)			
Property Boundary	128	25	450
Resident (feet)	5,827	250	64,000
Private Well	2,250	1,000	4,000
Public Well			
Number of Personnel			
Haz. Waste Ops.	35	1	200
Support Ops.	33	-(c)	205
Contractors	3	-	25
Total	113	4	1,500
Waste Transport			
Distance (miles)	25	-- no data --	

(a) Extracted from RTI91b, see text for details.

(b) Depending on how the data were displayed, the term "typical" may refer to the average or median value of a data set.

(c) No data cited or available.

4.0 OBSERVATIONS AND CONCLUSIONS

4.1 Class A Low-level Waste

This study's observations and conclusions regarding Class A waste are of two types:

- a) those pertaining to waste characteristics; and
- b) those addressing the adequacy of the database to support other waste management assessment activities.

4.1.1 Class A Waste

Licensed waste generators made 18,776 waste shipments to approved disposal facilities from January 1986 to November 1990. About 56 percent of these shipments were made by nuclear utilities, and about 70 percent of all shipments went to Barnwell.

The total volume and activity of waste shipped was 222,000 m³ and over 2.0 million Curies. Of this, over 95 percent of the volume and three to ten percent of the activity are associated with Class A waste.

Radionuclide concentrations of Class A waste varied widely, depending upon waste streams, with concentrations spanning eight orders of magnitude, from 10⁻⁶ to 10⁺² Ci/m³. For some radionuclides, concentration clusters were noted over a narrower range, from about 10⁻³ to 10⁺⁰ Ci/m³. The following typifies the range of concentrations for the five categories of waste generators.

Generator Sector	Range of Concentrations - Ci/m ³	
	Average	Maximum
Academic	10 ⁻² - 10 ⁻⁴	10 ⁻³ - 10 ⁻¹
Government	10 ⁻⁵ - 10 ⁻⁴	10 ⁻³ - 10 ⁻²
Industrial	10 ⁻⁵ - 10 ⁺¹	10 ⁻² - 10 ⁺²
Medical	10 ⁻⁴ - 10 ⁻²	10 ⁻³ - 10 ⁺⁰
Utility	10 ⁻³ - 10 ⁻¹	10 ⁻² - 10 ⁺¹

More than 90 percent of the activity of the Class A waste consisted of the following radionuclides:

H-3	Sc-46	Co-60	Tc-99	Cs-137
C-14	Cr-51	Ni-63	Ru-103	Cs-134
Na-22	Mn-54	Zn-65	Ru-106	Ce-141
P-32	Fe-55	Kr-85	Ag-110m	Ra-226
S-35	Fe-59	Sr-90	Sb-124	Th-232
Cl-36	Co-57	Nb-95	I-125	U-238
Ca-45	Co-58	Zr-95	I-131	

The following waste streams were most frequently reported:

- absorbed and stabilized liquids
- activated contaminated hardware
- activated contaminated concrete
- biological tissues and animal carcasses
- compacted and non-compacted trash
- dry solids
- spent de-watered resins
- spent scintillation fluid

4.1.2 Quality of the Database

The data contained in the individual shipping manifests and the data being compiled by the individual Compacts and unaffiliated States provide a wealth of information useful in assessing the potential impacts of the disposal of Class A waste. Some useful information is available on radionuclide inventories and concentrations, and the physical and chemical forms of each waste shipment and each container within each shipment. In addition, much of this information is available in electronic form through the MIMS database. The key question is whether the hard copy and electronic data are readily available and at a level of detail that can support a broad range of analyses. As was noted earlier, the database incorporates some inherent limitations in both the hard-copy and electronic data formats.

In practice, the data contained in the manifests are of limited use unless they are available in electronic form. The MIMS is accessible, but not all of the data on the manifests are available through its database. For example, all waste shipment data from Barnwell, and from Beatty and Richland prior to 1988, characterize waste at the shipment-level only, with no information provided at the container-level. Data characterizing radionuclides and their respective activity are aggregated over the entire shipment for each waste generator. As a result, radionuclide concentrations are averaged over the entire shipment. The variability of radionuclide concentrations among containers in a given shipment cannot be determined. The same constraint applies to the variability of nuclide concentrations for different waste streams. Moreover, all radionuclide concentrations were derived using the overall container volume or its total weight and not the actual waste volume or mass. The database does not provide the means to resolve the net volume or weight of each waste container. Overall, the data (in electronic form) are available at the container-level for only 15 percent of the shipments made between 1986 and 1990.

Another potentially significant limitation of the electronic database has to do with brokered waste. For brokered shipments, it is not possible to apportion radionuclide and activity levels directly to each generator or category of waste generator making

up a shipment. In addition, brokered waste shipments often include waste from out-of-region generators, making it difficult to assign shipments to specific Compacts or unaffiliated States. Because of these limitations, it is not possible to track waste containers and shipments from "cradle to grave," thereby making it difficult for waste Compacts and unaffiliated States to manage waste in their regions unless a new tracking system is instituted. From 1986 to 1990, brokered shipments constituted 22 percent of the volume and four percent of the activity of Class A waste.

The electronic data files are also limited by the way they characterize the chemical form of the waste. Generators enter data in the shipping manifests using two methods. The first one relies on codes to describe the waste forms. The codes are specified on the shipping document itself. The other method involves free-style entries that are not standardized and, consequently, each entry is unique. In order to extract and reduce the latter type of data, it would be necessary to review individual shipping manifests and process the information manually. This problem is further complicated by differences between the shipping manifest formats used by U.S. Ecology and Chem-Nuclear Systems, Inc.

In conclusion, if the data were used to estimate radionuclide inventories shipped for disposal, the limitations are not very important. However, the variability of radionuclide concentrations in individual waste streams and containers may have some implications for uses as evaluating the exposures and doses to workers handling the waste and applicability of various treatment options for such waste. The uncertainty in radionuclide concentration distributions, as a function of waste stream, may also have some implications if the data were used for performance assessment purposes, e.g., source term development.

4.2 Methods and Facilities to Treat and Dispose Non-Radioactive Waste Under Subparts C and D of RCRA

There is no single database available to support the assessment of various treatment and disposal options for such waste. The information presented in this report is based on a compilation of several databases and sources of information. As such, the quantity and quality of the data vary widely by waste management option. The discussion below summarizes future trends and the quality of the data for each option.

4.2.1 Treatment Options

The two major treatment options considered in this report are recycling and incineration. At this time (June 1992), recycling is in a state of flux. There is great pressure to divert as much material as possible from the municipal waste stream. More than

40 states have some form of legislated recycling goal (GER92). The market for recycled material has yet to catch up with the supply. The resultant market glut has depressed the value of the recovered materials, but steps now are underway to facilitate demand for products made from recycled material, e.g., procurement policies. The prevailing opinion, however, is that recycling is an integral part of municipal solid waste management. Its role is more likely to increase rather than decrease. The data for this treatment option is also in the developmental stage with regard to environmental fate and effects modeling - data exist for counts of collection programs and material recovery facilities, but transportation distances, manufacturing sites, and end-product use and distribution are much less well known.

Three separate categories for incineration are examined in this report - on-site incineration in a small combustor (such as a hospital), off-site incineration as a non-hazardous waste, and off-site incineration as a hazardous waste. General trends include an increase in the incineration of municipal waste (to reduce volume) and hazardous waste (to destroy pollutants). Less certain is the status of small hospital or biomedical incineration facilities. They are less regulated than the other categories, but may come under closer scrutiny in the future.

These three categories are also rank-ordered in terms of data quality. Hospital and biomedical research incinerators are the least known; their capacity and waste type generally exempt them from federal regulations. The only available information is from a subset of a database for hospitals located in New York. Even a count of all facilities is difficult to obtain.

As of February 1991, there are federal emission guidelines and regulations for municipal trash incineration facilities. The emission guidelines can form the basis for environmental fate and effects modeling. The number of municipal incinerators is sufficiently small (about 200), that there are accurate count, location, and capacity data. Population data in the immediate vicinity of the sites are lacking, and would have to be determined from issued permits or census data.

As a category, hazardous waste incinerators have been well characterized, using the results of the 1986 nationwide survey. A database of currently permitted facilities and federal performance standards have been compiled by EPA. The only limitation is the absence of meteorological data for all incinerator sites and population distributions around such sites.

It is also important to note that incinerators and landfills generally are not co-located. The transportation corridors from the point of generation to incinerators and from incinerators to the landfills must be developed, as this information is also not available.

4.2.2 Disposal Options

There are three inter-related trends for municipal waste landfills. First, they are decreasing in number. In 1985, a census counted approximately 7,000 landfills nationwide. The 1986 survey estimated a landfill population of approximately 6,000 facilities. Estimates made in this study reveal that there are about 5,000 active landfills, based on state data available in 1990. The number of active landfills is expected to decline over the next few years due to landfill regulations that were promulgated by EPA on October 9th, 1991 (EPA91a). The regulations state that any landfill that closes within 24 months of the promulgation date need meet only the requirements for the final cover. There is an exemption for some small (<20 tons/day) landfills in arid or remote areas where closing would be a hardship.

Second, the smaller number of landfills will result in an increase in the average distance to a landfill. New York and New Jersey are still expected to ship waste across several states to find landfill disposal capacity.

Third, the 1991 regulations require that all new landfills and lateral expansions will be required to have a composite liner made of a synthetic material covering a two-foot layer of compacted soil with a hydraulic conductivity not exceeding 1×10^{-7} cm/sec, include a leachate collection system, and include a groundwater monitoring system (EPA91a). The extra expenses of these new requirements, combined with the difficulty in siting new facilities (e.g., public acceptance), means that landfills will tend to be larger than in the past.

EPA developed a data base with approximately 1,000 landfills to support the new regulations. These data indicate a wide variation in the underlying geology and hydrogeology of landfill sites. As site conditions are not expected to change, the emphasis will focus on the design requirements for liners, leachate collection systems, and monitoring systems for the purpose of environmental protection.

There are no new regulations concerning the general design and siting of hazardous waste landfills. Regulations concerning waste forms and concentration levels sent to a hazardous waste landfill, however, continue to evolve (40 CFR 268.10-268.12; EPA91b). For many wastes, these land disposal restrictions require treatment (such as incineration or neutralization) prior to disposal in a hazardous waste landfill.

The 1986 survey data for 133 hazardous waste landfills are likely to be representative of the current population of sites. An important trend is that most hazardous waste landfills do not accept waste from other generators, that is, there are very few

commercial hazardous waste landfills. The number of hazardous waste landfills will continue to increase as more companies seek disposal for their hazardous waste.

For the purpose of evaluating environmental effects, the most difficult data to obtain are population distributions around the sites. There are estimates for populations within a mile of the site for both hazardous and non-hazardous waste landfills, but there is no information available for populations located at greater distances.

4.2.3 Other Considerations

A rank-ordering of the treatment and disposal methods, according to the quality and quantity of information, reveals that the order parallels the hazardous properties of the waste. Most of the data are for hazardous waste incinerators and landfills, followed by municipal (non-hazardous) waste landfills, and incinerators. In all cases, the population densities around such sites are poorly characterized.

Just as important, is the lack of information about other disposal methods. There are some data for hospital and biomedical incinerators, but many parameters would still have to be defined in support of waste management and assessment analyses. There is also a lack of useful information about other disposal methods, such as industrial landfills, surface impoundments, and land applications. These disposal methods fall under state and general federal requirements (40 CFR 257).

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