NUREG/CR-6147
Vol. 2

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

Main Report – Part A

Prepared by
J-C Dehmel, D. Loomis, J. Mauro/SC&A
M. Kaplan/ERG

S. Cohen & Associates, Inc.

Eastern Research Group, Inc.

Prepared for
U.S. Nuclear Regulatory Commission

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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.

Donald A. Cool

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Radiation Protection and Health
Effects Branch
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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 Unaffiliated States - Analyses at the container level Non-Brokered Waste: Aggregate Practices 1988-1990
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 Aggregate Practices 1986-1990

Volume 5:

F Waste Radionuclide Concentrations by Compact Regions and States - Shipment-level Analyses: All Disposal Sites and 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 for Selected Radionuclides and States: Aggregate Practices from 1986 to 1990
I Utility Waste Forms and Radionuclide Concentrations - Container-level Analyses for Selected Waste Forms: Beatty and Richland 1988 to 1990
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K Processed and Brokered Wastes - Selected Waste Forms and Radionuclides: Container-level Analyses Aggregate Practices from 1988 to 1990
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 (LLRWPAA) 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.

ACKNOWLEDGEMENTS

S. Cohen & Associates, Inc. would like to take this opportunity to acknowledge the efforts and participation of the Nuclear Regulatory Commission staff, namely Messrs. Robert Meck, James Malaro, Paul Kovach, and Steve Klementowicz.

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.

1.0 INTRODUCTION

1.1 Purpose

The U.S. Nuclear Regulatory Commission (NRC) has initiated this study to further refine the characterization of Class A low-level radioactive waste. The characterization was performed for each category of waste generators, namely academic, government, industrial, medical, and utility nuclear power plants. 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 sponsored by the Department of Energy (DOE) and maintained by EG&G Idaho, Inc. (EG&G). The database captures information from waste shipment manifests from 1986 to 1990. Supplementary sources of data include studies sponsored by the Nuclear Regulatory Commission, Department of Energy, low-level waste Compacts and unaffiliated States, and trade organizations.

A database management program was developed for accessing, sorting, 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 waste listed in shipping manifests. The results of the analyses are summarized in tables, histograms, and cumulative radionuclide concentration distribution curves by waste streams, generators, and regions.

1.2 Scope

This report includes:

(1) A list of the major generators of Class A waste, their geographical locations, and the annual quantities of waste generated. These generators produce the majority of the waste generated on a national scale.

(2) A description of the physical, chemical, and radiological properties of the waste. The description also addresses some of the major potential sources of variations in these properties.

This report supplements the information provided in an earlier NRC report entitled, "Characteristics of Low Level Radioactive Waste Disposed During 1987 Through 1989," issued as NUREG-1418 by the Office of Nuclear Material Safety and Safeguards, December 1990 (NRC90). The data in NUREG-1418 are presented according to waste class, year of disposal, disposal facility, category of waste generator, waste streams, solidification agent, and sorbent media. The total activity shipped for disposal is provided, along with waste volumes.

This report supplements that information by providing the range and distribution of individual radionuclide concentrations in the various Class A waste streams.

This report also provides information characterizing current methods and facilities being 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). This information includes a list of disposal options, the geographical locations of the processing and disposal facilities, and a description of the pertinent characteristics of such processing and disposal facilities.

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

2.0 TECHNICAL APPROACH AND METHODS

2.1 Overview of the Database

Class A low-level radioactive waste is a subset of the total volume and activity of low-level radioactive waste disposed at licensed low-level radioactive waste disposal facilities. Table 2-1 presents the total volume and total activity of all radioactive waste shipped for disposal by category of waste generators and by year, from 1986 to 1990. This table includes all waste (i.e., Classes A, B, and C, brokered and non-brokered). Table 2-2 presents a subset of this waste that includes only Class A waste. As may be noted, Class A waste constitutes over 95 percent of the volume, but only about 3 to 13 percent of the activity of the waste.

The primary objective of this report is to characterize the sources of the waste, waste streams, and radionuclide concentration distributions (Ci/m^3 and pCi/g) contained in Class A waste shipped for disposal by each category of waste generators. Given the information provided in the shipping manifests, waste volumes reflect total container volumes, recognizing that actual waste volumes may in fact be less. The same is true for container weights, as the reported weight of the waste includes that of the container. In either case, the database does not provide the means to obtain the net volume or weight of the waste.

The characterization of low-level radioactive waste provided in this report is based primarily on information available from the National Low-Level Waste Management Program's database, known as "MIMS" (abbreviation for the Manifest Information and Management System) (EGG90). The MIMS contains data encoded from the shipping manifests that accompany each waste shipment. The Program is sponsored by the Department of Energy (DOE) and maintained by EG&G Idaho, Inc. (EG&G).

In using the results presented in this report, the inherent limitations of the MIMS database should be clearly understood. It should be noted that the data presented here rely on several sources of information specifically chosen for the purpose of complementing these limitations. The data from NUREG-1418 and EPRI NP-5526 were used for this purpose (NRC90, EPR88). Similarly, additional information was obtained from the MIMS on-line system, which provides the means to conduct analyses beyond the data presented in the shipping manifest alone (MIM91, EGG84). The data used in this report were bench-tested with the MIMS on-line service to verify that both waste volume and activity totals were being properly manipulated and summed. Close resolutions, within a percent, were obtained with the MIMS data.

Table 2-1 Yearly Activity (Ci) and Waste Volumes (m^3) of All Waste Shipped for Disposal[a]

Year	Academic	Government	Medical	Industrial	Utility	Total
1986						
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
1987						
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
1988						
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
1989						
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
1990						
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
Total						
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	[illegible]

(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). 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 2-2 Estimated Yearly Activity (Ci) and Waste Volumes (m^3) of Class A Waste Shipped for Disposal[(a)]

Year	Academic	Government	Medical	Industrial	Utility	Total
1986						
Volume	1.18E+3	2.31E+3	7.82E+2	1.67E+4	2.29E+4	4.38E+4
Activity	8.57E+1	4.50E+3	2.32E+1	4.65E+4	4.43E+3	5.55E+4
1987						
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
1988						
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
1989						
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
1990						
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 taken from NUREG-1418 NRC90). For 1990, waste data were obtained from the DOE/EG&G MIMS on-line service (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.

Any differences were due to the fact that the data did not cover the full year of 1990, as EG&G did not include the last eight weeks of the year and that some waste contained in the database originated from other sources. Finally, a clear distinction is made among the various sources of information used in this study:

1) The EG&G data used in this study are a subset of the DOE/EG&G MIMS database,

2) The MIMS database on-line service (remote access) was used to supplement the EG&G data and validate data sorts and analyses from the program developed for this study, and

3) Several reports and studies were used to complement the above noted sources of data and information.

It was also recognized that U.S. Ecology or Chem-Nuclear Systems, Inc. offer a better source of data since they routinely compile all of the shipping manifest data into their respective database management systems. However, limited project resources did not provide the means to purchase the data from these firms. Data already available to the NRC, in both hard copy and computer files, could not be used in this effort, as it was procured under confidentiality agreements between the NRC and disposal site operators.

Regarding the use of other sources of information, such as NUREG/CR-4370 (NRC86a), ONWI-20 (as summarized in NUREG/CR-4370), Semi-Annual Effluent Reports (NRC89), and DOE's Integrated Data Base (DOE90a), it is recognized that these references include some uncertainties, but have been retained for historical perspectives. For this study, information from NUREG-1418 and EPRI NP-5526 were used instead, since they are more reliable (NRC90, EPR88). Data characterizing mixed waste were extracted from the National Profile on Commercially Generated Low Level Radioactive Mixed Waste, presented in NUREG/CR-5938 (NRC92).

The shipping manifest used to describe low-level waste is a relatively complex document. Appendix A presents two examples of typical waste manifest forms (USE88, CNS90). The cover sheet provides information about the waste generator (facility name and address), generator identification code and disposal site access number, carrier or transporter, summary of shipment totals, and statements of certification. The continuation sheet provides detailed information for each waste container making up the shipment.

Based on the information provided in the cover sheet of each manifest, a waste generator is categorized as academic, government, industrial, medical, or nuclear utility. As a result, it has become common practice to sort the information characterizing low-level waste by these categories. As will become apparent in the chapters that follow, the practices that result in the production of low-level waste within the academic, government, medical, and industrial sectors are often similar in waste streams and radionuclide contents. However, the distribution of the radionuclides and their respective concentrations will vary.

Each entry in the continuation sheet of the shipping manifest provides the following data: container number, type of container, container volume and total weight, physical and chemical characteristics, waste and stability classifications, and a listing of each radionuclide and associated activity level. Information is also provided on the amount of source and special nuclear materials, radiation and contamination levels, and Department of Transportation (DOT) shipment classifications and labeling. Waste brokers use similar shipment manifest forms with some minor variations to account for waste coming from two or more states or generators. It was not possible to verify the accuracy of individual radionuclide activity entered into the shipping manifests and MIMS database. It is recognized that in some cases, the presence and reported activity may in fact vary significantly than that actually contained in the waste.

Data on low-level waste summarized in this report were made available in electronic files by EG&G Idaho, Inc. (EG&G) for all three disposal sites (Barnwell, SC, Beatty, NV, and Richland, WA). This information was supplemented by data obtained from the MIMS through direct on-line access. Additional and complementary information was culled from reports and studies sponsored by the Nuclear Regulatory Commission, Department of Energy, regional Compacts and unaffiliated States, and trade organizations.

It should be noted that a fourth disposal site (Envirocare, located in Utah) has been allowed to receive "low activity" waste, in addition to materials bearing naturally occurring radioactivity. This information, however, has not been captured by the DOE/EG&G database and is not included here.

The electronic files supplied by EG&G contain low-level waste data provided at either the "shipment level" or the "container level." Throughout this report, the terms:

- "Shipment-level" data means that the electronic data available for a given shipment have been aggregated such that the information pertaining to individual containers comprising the shipment is not provided. Accordingly, shipment-level data consists of the total volume and total inventory of individual radionuclides in each shipment.

* "Container-level" data means that the electronic data include information on each container comprising a given shipment, i.e., the inventory of all radionuclides and the total waste volume and weight of each container. Container-level data are the most useful since they provide the most comprehensive information with which to estimate individual radionuclide concentrations in waste containers.

Shipment-level data are available in electronic form for five years, from 1986 to 1990, for all three disposal sites (MUN90, MUN91).[1] Container-level data, however, are available from the MIMS 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.

Some type of information, though available in electronic form, are not included in this report. For example, some of the shipping manifest entries addressing specific requirements of the disposal sites or DOT are not included in the database because they are not relevant to this study. In addition, generator and facility names and addresses were not provided by EG&G because the electronic data characterizing waste shipments identify waste generators and brokers only by codes and states. However, the identities of the principal generators of low-level waste are available from other sources, primarily from yearly surveys conducted by Compacts and States. This information is also provided in this report, whenever made available by the regional Compacts and States.

The database obtained from EG&G consists of 18,776 shipping, 103,355 container, and 705,387 radionuclide records. Figure 2-1 presents the overall structure of the database. The manifest database is broadly segregated according to unbrokered versus brokered waste shipments. Unbrokered waste shipment data reflect data characterizing individual waste shipments made by a specific waste generator. Accordingly, all of the data, whether available at the shipment level or container level, pertain to a specific waste generator.

Brokered waste shipment data reflect individual waste shipments made by a specific waste broker or processor. In this context, the shipment contains waste from one or more waste generators.

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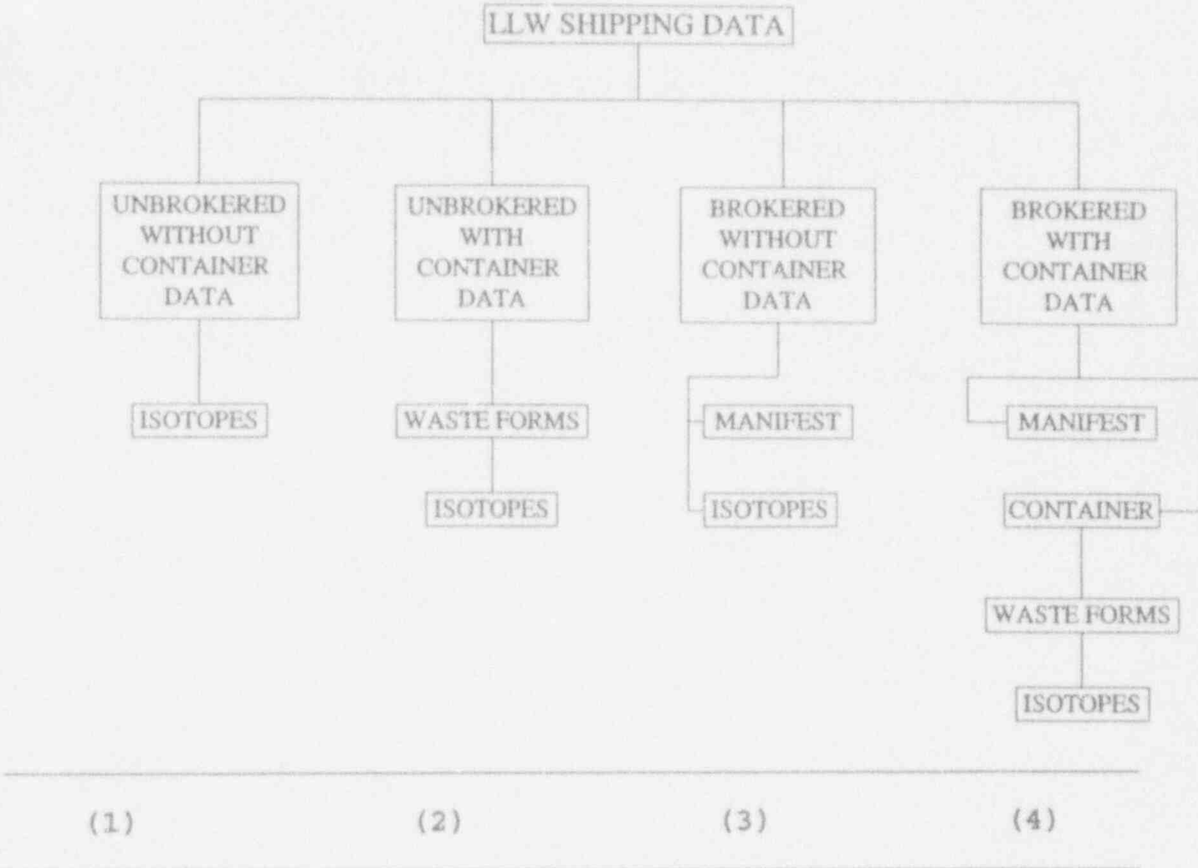
[1] At the time of the preparation of this report, the data were available from the MIMS only from 1/86 through 11/90. The loading of the manifest data is an on-going process, however.

Figure 2-1   Overall Structure of LLW Database



(1) No information on waste forms or streams; nuclide activity given as an aggregate for entire shipment and by generators.

(2) Best resolution of LLW data for each generator by waste forms or streams and nuclides. Limited number of shipments with data at the container level.

(3) No information on waste forms or streams; nuclide activity given as an aggregate for entire manifest. Impossible to directly reapportion nuclide and activity to each generator contributing to the entire shipment. Brokered manifests typically include waste from out-of-region generators.

(4) Information provided down to waste forms or streams and by isotopes. Impossible to directly reapportion nuclide and activity to each generator class making up the entire shipment. Best use of data is for conducting waste stream or form analyses independent of generator class.

For brokered shipments, the MIMS data are aggregated such that the information cannot be apportioned to individual categories of waste generators.

The following tabulations present the total number of direct shipments made by each category of waste generators. In this table, brokered shipments are included under "Industrial" even though the shipments include waste produced by all categories of waste generators. As indicated, the data for Richland and Beatty contain manifest data that can be accessed at both the shipment and container level.

However, 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.

	Richland and Beatty Records		Shipping Records		
Generators	Shipping	Container	Barnwell	Beatty	Richland
Utility	1,408	21,023	9,308	287	1,057
Government	99	3,929	571	128	66
Academic	24	2,492	203	1	384
Medical	2	112	15	0	1,032
Industrial	1,368	75,799	2,949	557	2,218
Total	2,901	103,355	13,046	973	4,757

The fractions of the shipments that provide data at the container level and the distribution of the container data among the categories of waste generators are as follows:

		Shipments With Container Data		
Generator Category	Total Shipments	Number	Fraction of Shipments	Distrib. of Containers
Utility	10,652	1,408	0.13	0.203
Government	765	99	0.13	0.038
Academic	588	24	0.04	0.024
Medical	1,047	2	0.002	0.001
Industrial	5,724	1,368[2]	0.24	0.733
Total	18,776	2,901	0.15	1.00

[2] The number of industrial shipments at the container level is relatively larger because brokered shipments are included in the "industrial" sector.

The tabulation reveals that, 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 (i.e., 13,046 + 973 + 4,757) of which only 2,901 contain data at the container level. This means that radionuclide concentration distributions for specific categories of waste generators and specific waste streams can only be based on a subset of the entire database.

The container-level data can be further subdivided according to the size of the containers. Container sizes vary from 0.02 to about 1,500 ft^3 (NRC90). Some container sizes, however, are used more often than others. For example, the 55-gallon drum (7.5 ft^3) is used most often (80 percent) by all waste generators (NRC90). A breakdown of container counts by volume based on Beatty and Richland data is given in Table 2-3.

In reviewing the results presented in this report, a clarification must be made regarding the use of the data in various applications, such as source term development in risk assessment analyses (environmental and occupational), waste characterization, preparation of new waste shipping manifest forms, development of a regional waste tracking system, etc. The users should thoroughly understand the inherent limitations of the data and results. In some instances, the limitations are inherent of waste generation practices rather than how the data are actually entered into shipping manifest forms. Accordingly, when using the data presented in this report, the usefulness and uncertainty of the results should be kept in the context of what is known of actual waste generation and disposal practices.

2.2 Limitations of the Database

The LLW database includes several inherent limitations that must be recognized in order to properly interpret the results or draw any conclusions. Some of these limitations are associated with generator disposal practices, while others are due to differences in how the data are maintained and coded at the disposal sites.

2.2.1 Direct Shipments to Barnwell (all years) and Beatty and Richland for 1986 and 1987

All waste shipment data from Barnwell, and from Beatty and Richland prior to 1988, characterize waste at the shipping level only. There is no information at the container level. Data characterizing radionuclides and their respective activity are aggregated over the entire shipment for each waste generator.

Table 2-3 Richland and Beatty Container Size Distributions[a]

Waste Container Volume (ft^3)	Container Distribution Number	Percent
< 1	1,560	1.5
1 to 5	2,945	2.8
6 to 10[b]	82,923	80.2
11 to 50	10,843	10.5
51 to 100	3,272	3.2
> 100	1,812	1.8
Total	103,355	100

(a) Aggregate data from 1988 to 1990 for all categories of waste generators. Extracted from EG&G database (MUN91).
(b) This range includes the 55-gallon steel drum with a volume of 7.5 ft^3.

As a result, the estimates of radionuclide concentrations are averaged over the entire shipment. The variability of nuclide concentrations among containers, in a given shipment, cannot be determined. In addition, the variability of radionuclide concentrations of different waste streams cannot be discerned.

2.2.2 Brokered Shipments to Barnwell (all years) and Beatty and Richland for 1986 and 1987

All data characterizing brokered shipments to Barnwell, and Beatty and Richland prior to 1988, summarize data only at the shipping level. As above, there is no information at the container level because data characterizing radionuclides and their respective activities are aggregated over the entire shipment. Furthermore, brokered shipments have an additional limitation; it is not possible to directly apportion radionuclide and activity levels to each waste generator making up the shipment. Also, brokered waste shipments often include waste from out-of-region generators, making it difficult to assign shipments to specific Compacts or unaffiliated States.

2.2.3 Direct Shipments to Beatty and Richland for 1988 to 1990

Direct shipment data from Beatty and Richland characterize waste at the container level. This data set provides the best resolution of the information for each generator by waste streams and radionuclides at the container level. The only limitation is that the data represent only a small fraction of the information characterizing all waste at the container level and are available for only three years.

2.2.4 Brokered Shipments to Beatty and Richland for 1988 to 1990

Data characterizing brokered waste shipments to Beatty and Richland for 1988 to 1990 are provided only at the container level. However, it is not possible to apportion radionuclides and amounts of activity at the container level for each generator making up the shipment. The best use of the data is to characterize waste at the container level, irrespective of the category of generators that produced it. These data sets contain the largest amount of information at the container level, but are of limited use because they cannot be apportioned to individual waste generators.

2.2.5 Data Truncations at the Disposal Sites

Waste radionuclide activity levels may at times be entered into the database as default values. For example, a shipping manifest entry characterizing radionuclide activity as a "less than" value, i.e., <0.001 mCi, would be entered into the database as 0.001 mCi. In other instances, some radionuclides are not entered into the database depending upon the half-life or activity levels. For short-lived radionuclides, the activity may have totally decayed by the time the shipment is processed at the disposal site. These adjustments are made at the disposal sites. In the first instance, the inventory and concentration of the radionuclide is overestimated, while in the second case, the radionuclides, though present, are not reported.

2.2.6 Database Adjustments and Corrections

Periodically, the disposal site operators inform the Department of Energy and EG&G Idaho, Inc., of corrections for previously submitted data. Such corrections involve updating activity levels, waste volumes, or waste re-classification (e.g., from Class A to B). Corrections are usually made at the shipment level and only for data summarizing waste activity or volume totals. These adjustments are usually not translated down to the container level. Because of the size of the database, it is not possible to review individual waste shipping manifests to trace such inconsistencies. For example, when reviewing the information characterizing a waste container, it is not possible to determine if an inconsistency is due to key punch errors made at the disposal site or a mistake made by the generator when filling out the shipping manifest forms. The types of errors made by the waste generator, for example, may include an improper assessment of how much activity is actually contained in waste drums, invalid transcriptions of data from drum inventory forms to shipping documents, failure to make decay corrections for short-lived radionuclides, waste class misclassification, and erroneous description of the waste streams.

2.2.7 Waste Disposal Site Usage

It is common practice for some of the major waste generators to have access to two disposal sites. Over the years, a few generators may have even shipped waste to all three sites. These arrangements are made by the generator or via a waste broker. It is not possible to identify such practices from the database, as it only provides generator identification codes which are unique to each disposal site, thereby making it impossible to differentiate these generators from others. Furthermore, the database includes all generators that ever shipped waste for disposal, whether or not they are currently still shipping waste. Accordingly, a generator count, based on unique identification codes, would not reflect the current distribution and number of waste generators in a Compact or State. Finally, since some waste generators may have more than one identification code, the number of waste generators may be overestimated.

A fourth disposal site (Envirocare, located in Utah) has been allowed to receive "low activity" waste. This information, however, has not been captured by the DOE/EG&G database.

2.2.8 Coded vs Non-Coded Shipping Manifest Entries

Data contained in the shipping manifests are entered by generators using two methods. The first one relies on codes to describe the waste streams. The codes are specified on the shipping document. The other method involves free style entries that are not standardized, 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 the differences between the shipping manifest formats used by U.S. Ecology and Chem-Nuclear Systems, Inc. (see Appendix A for details). The disposal site operator, however, may assign a code based on the written information. Another complication involves containers that include different types of waste. Typically, the manifest entry describes the most predominant waste stream or form.

2.2.9 Biases in Reporting Radionuclide Inventories in Waste Shipments

Given the format and content of the database, it is not possible to characterize actual waste generation and disposal practices of the various waste generators. Research and production activities change because of licensing and regulatory requirements and also due to business and competitive forces. It is only possible to present a broad overview of such practices, recognizing that such a description is only a snapshot characterization.

Generators primarily obtain radioactive materials from various suppliers. Other sources include university reactors and accelerators, which generally produce smaller quantities of short-lived radionuclides. Once a shipment of radioactive material is received, it is first inspected for damage or leakage. Next, the material is assayed and distributed in its entirety or fractionated for use in experiments or production activities. Typically, research or production protocols require that the amounts of radioactivity introduced into a process be tracked in order to determine if the process is successful. This information is also used to maintain a running inventory of radioactive materials. Periodically, typically monthly, the inventory is updated to reflect the amounts of radioactive materials going into the various streams of the process. For example, some materials may be released into a chemical or industrial sewer, discharged into ventilated enclosures (hoods, glove-boxes, etc.), introduced into animals or products, contained in various types of waste, or may have simply decayed away. The radioactive material inventory system is intended to account for these various end-points.

Depending upon the complexity of the process, the inventory system may be simple or sophisticated. Simple systems, for example, assume that the balance of radioactive materials not accounted for in the process ends up as waste. This amount is entered into records listing how much radioactivity is being added into waste containers. This amount is not always corrected for radioactive decay, which tends to overestimate the actual amount of activity. Sophisticated inventory systems, on the other hand, keep track of materials by accounting for the amounts and radioactive decay in each step of the process or waste stream. Some users also assay each waste and process stream to make an accurate assessment of the remaining radioactivity.

Eventually, the data entered in each waste container record is used to prepare a shipping manifest. The information is simply transferred from one document to another, without always making any corrections for radioactive decay, since the waste container might have been held in storage for some time. In some instances, waste activity levels may be entered on the shipping record as "less than" values, e.g., <50.0 uCi. This practice is often adopted as it may not always be practical to account, in the aggregate, the individual amounts of radioactivity placed into a waste container. This may occur when multiple users put various amounts of radioactive materials, some in large quantities and others at trace levels, in a single waste drum. This procedure may result in overestimating the actual amount of activity destined for disposal.

For nuclear power plants, the activity reported for some radionuclides is believed to be overestimated (e.g., C-14, Tc-99, or I-129), as the activity of these radionuclides is inferred by using scaling factors (ROB91). The scaling factor relates the presence of a radionuclide (occurring at very low concentration or that is difficult to analyze) based on the presence of one that is easily detected (e.g., Co-60 or Cs-137). The presence of transuranics (e.g., Am-241) reported in waste shipments is also overestimated for the same reasons. This situation has persisted because these radionuclides do not influence the classification status of the waste (ROL92). Waste generators may find this approach acceptable, as along as there is no financial or regulatory penalty for over reporting the activity. However, over reporting may have an impact on the radionuclide inventory of the disposal facility receiving the waste (ROL92).

Uranium and thorium reported by industrial waste generators, fuel-cycle facilities, or certain source material licensees are also believed to be exaggerated. In addition to analytical errors, the major cause of the overestimate is believed to be the method that is used to derive the mass of the source material. Typically, it is derived by multiplying the specific activity of the waste by the mass of the waste. If the amount of source material is small, using the total mass of the waste will grossly exaggerate the total activity.

2.2.10 Impacts of Waste Volumes and Weights on Radionuclide Concentrations

An examination of the sorts conducted using the EG&G data revealed that a radionuclide concentration value of 4.7E-06 Ci/m^3 appears frequently. The amount of activity reported in a 55-gallon drum is often cited as 1 microcurie. Since a 55-gallon drum is 0.212 m^3, the resulting calculation yields a concentration of 4.7E-06 Ci/m^3. As was noted earlier, waste radionuclide concentrations are based on the container volume and not the actual waste volume. The data do not provide the means to resolve the net waste volume from shipping manifest entries.

A similar case might be made for mass concentrations reported in pCi/g. Applying the same procedure, a mass concentration of 43 pCi/g is derived for a 55-gallon drum, type 17H, opened-head, with lid, and complete closure ring, weighing 51 pounds. However, this artifact does not appear as often as there is much more variability in container weights than volumes. Other materials often added in a waste container include liners, sorbents, and, at times, an inner container, e.g., a 30-gallon drum or 5-gallon pail. It should be noted that the mass concentrations reported in this study are based on the total weight of the container and any other non-waste materials included in it. The database does not provide the means to resolve the net weight of the waste.

2.2.11 Configuration of Compacts and Unaffiliated States

The study is based on the configuration of the Compact regions and unaffiliated States as of 1990 (DOE91). Since then, there has been some changes. 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 (Richland). The Beatty disposal site has since been closed. 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 reflects practices that predate these realignments.

2.2.12 Waste Densities

Since the EG&G database does not provide the weight of the waste for shipments from Barnwell (all years), and only 1986 and 1987 for Beatty and Richland, waste densities were calculated separately for those waste shipments with given container weights and volumes. The results were then used as default waste densities in calculating mass concentrations.

Tables 2-4 to 2-6 characterize low-level waste densities as a function of waste classification, i.e., Class A (stable and unstable) and for selected waste streams. Waste densities typically range over two orders of magnitude, from 0.21 to 5.34 g/cm^3, across all waste generators and waste streams. As anticipated, waste densities are higher for stabilized waste. These results reflect data characterizing 1,094 shipping and 66,812 container records.

Overall average waste densities by sector and across all waste streams are 0.57, 0.70, 0.78, and 1.02 g/cm^3 for academic, governmental, medical, and industrial waste generators, respectively. Comparing these waste densities to those shown in Table 2-4 indicates that the values given above rearly approximate those of Class A-Unstable waste at about the 50th percentile.

Table 2-4 Institutional and Industrial Class A-Stable and A-Unstable Waste Densities[a]

Parameters	Academic	Government	Medical	Industrial
	--- Low-Level Waste Density (g/cm³) ---			
Class A-Unstable				
1st percentile:	0.35	0.25	0.39	0.21
10th :	0.42	0.56	0.58	0.36
50th :	0.67	0.82	0.76	0.87
75th :	0.81	0.91	0.79	1.26
90th :	0.89	1.37	0.83	2.01
99th :	1.37	1.52	0.91	2.81
Based on No. of				
Shipping records:	21	57	1	981
Container records:	2,323	2,850	109	60,195
Disposal site(s):	R[b]	R	R	R
Class A-Stable				
1st percentile:	0.86	0.92	---	0.26
10th :	0.86	0.92	---	0.50
50th :	3.76	0.94	---	1.10
75th :	3.77	1.55	---	2.35
90th :	3.79	2.15	---	3.66
99th :	3.79	2.24	---	5.34
Based on No. of				
Shipping records:	1	7	0	26
Container records:	5	8	0	1,322
Disposal site(s):	R	R	R and B	B

(a) Includes weight of the waste and container. Based on Richland and Beatty disposal sites data from 1988 to 1990 for non-brokered waste shipments only.
(b) Abbreviations signify: R for Richland and B for Beatty.

Table 2-5 Institutional and Industrial Low-Level Waste Streams and Average Densities[a]

Waste Streams	Waste Density - g/cm³ -- Range --	Average
Dry Solid	0.39 - 3.66	1.47
Non-compacted dry active waste	0.45 - 1.68	0.79
Solidified liquid	1.17 - 2.15	1.45
Solidified oil	1.06 - 1.55	1.22
Compacted dry active waste	0.36 - 1.77	0.75
Absorbed aqueous liquid	0.53 - 1.13	0.83
Animal carcasses in lime & sorbent	0.53 - 0.73	0.59
Solidified resins	1.21 - 1.52	1.35
Resins & dewatered resins	0.75 - 0.95	0.88
Non-cartridge filter media	1.26 - 1.43	1.35
Activated metals & concrete	3.1	-na-
Evaporator bottoms	1.35 - 1.60	1.48
Cartridge filter media	0.69 - 1.53	1.11
Biological - other	1.47	-na-
Aqueous liquid in vials	0.53	-na-
Other waste	1.11	-na-

(a) Result summary from data extracted from tabulations shown in Appendix C. Includes weight of the waste and container.

Table 2-6 Average and Density Distributions for Utility Low-Level Waste[a]

Waste Streams	Average Density[b] (g/cm³)
Dry solid:	0.86
Compacted dry active waste:	0.80
Non-compacted dry active waste:	0.59
Solidified liquids:	1.68
Solidified oils:	1.20
Solidified resins:	1.46
Dewatered resins:	0.81
Evaporator bottoms:	1.53
Non-cartridge filter media:	1.14

Parameters	Overall Distribution Density (g/cm³)[a] Class A-Unstable	Class A-Stable
1st percentile:	0.31	0.55
10th :	0.58	0.59
50th :	0.96	1.36
75th :	1.26	1.51
90th :	1.58	1.58
99th :	1.84	1.73
Based on No. of		
Shipping records:	1,230	42
Container records:	20,801	68

(a) Based on Richland and Beatty disposal sites data from 1988 to 1990 for non-brokered utility waste shipments. Includes weight of the waste and container.
(b) Result summary from tabulations shown in Appendix I for waste shipped to Richland in 1989.

The data presented in Table 2-5 were selected to characterize typical waste densities based on the highest number of shipping records and waste containers for either Richland or Beatty. This table summarizes waste densities given in Appendix C tabulations for each of the 16 reported waste streams. A review of these results show that average waste densities fall within the range of values shown in Table 2-4 for both streams Class A waste.

For nuclear power plants, waste densities vary from 0.31 to 1.84 g/cm^3, across Class A-Unstable and Class A-Stable waste and selected waste streams (see Table 2-6).

2.2.13 Use of Solidification and Sorption Agents

Waste generators are disposing Class A waste using stabilization media even though 10 CFR 61 does not require it, unless it is commingled with Class B or C waste. Disposal site operators have followed through by identifying and coding such waste. The shipping manifests list the codes for various types of solidification and sorbent agents. Table 2-7 lists a number of waste streams and sorption and solidification media that are authorized by the Beatty and Richland disposal sites. However, there are differences in the codes listed on the shipping manifest forms used by the two disposal site operators.

Some waste generators may use two or more stabilization agents in the same waste container. The manifest and the database may only reflect the most predominant one. Finally, it is not uncommon to see unspecified agents being reported in shipping manifests without any additional information. Accordingly, the characterization of the waste by stabilization agents may not truly reflect actual practices.

2.2.14 Container Use and Radionuclide Concentration

Waste generators routinely use a wide variety of containers and sizes, e.g., from 30-gallon drums to large 1,500 ft^3 containers NRC90). Some container sizes, however, are used more often than others. For example, the 55-gallon drum (7.5 ft^3) is used most often (80%) by all waste generators (see Table 2-3). Other container sizes are used infrequently to meet specific disposal needs. When compared to other waste generators, the medical sector, for example, tends to use smaller containers, e.g., 5-gallon pails and 30-gallon drums. Larger size containers are used by facilities producing greater waste volumes, typically industrial and utility waste generators. Larger containers include, e.g., metal boxes (32 to 104 ft^3) and 83-gallon drums (11.3 ft^3).

Table 2-7 Waste Absorption and Solidification Agents Authorized by the Beatty and Richland Disposal Sites

Waste Codes[a]	Waste Streams
02	Dry solids
03	Solidified liquids
04	Biological - other than carcasses
08	Dewatered resins
09	Solidified resins
10	Absorbed aqueous liquids
11	Absorbed non-aqueous liquids
12	Non-aqueous liquids in absorbents - vials
13	Aqueous liquids in absorbents - vials
14	Animal carcasses in lime and absorbents
15	Gas
20	Evaporator bottoms
21	Compacted dry active waste
22	Non-compacted dry active waste
23	Cartridge filter media
24	Non-cartridge filter media
25	Activated reactor hardware
26	Solidified chelates
27	Solidified oil
99	Other

SOLIDIFICATION AND SORPTION AGENTS

Waste Codes[a]	Solidification and Sorption Agents[b]
02	Speedi dry
03	Celatom
04	Floor dry - superfine
05	Hi-dry
06	Florco and Florco X
07	Instant dry
08	Safe-T-Sorb
09	Oil Dri - Safe-N-Dri
10	Zonolite Grades # 2,3,4

Table 2-7 Waste Absorption and Solidification Agents Authorized by the Beatty and Richland Disposal Sites, Cont'd

SOLIDIFICATION AND SORPTION AGENTS, Cont'd

Waste Codes[a]	Solidification and Sorption Agents[b]
11	Dow Media
12	Concrete - structural
13	Asphalt
14	Delaware custom media
15	Envirostone
16	Krolite
20	Florco
21	Florco X
22	Opalex
23	Solid-A-Sorb
24	Chemsil 30
25	Chemsil 50
26	Chemsil 3030
27	Dicarpel HP200
28	Dicarpel HP500
29	Petroset
30	Petroset II
31	Aquaset
32	Aquaset II
33	Safe-T-Set
34	Aztech - GE
35	Aquaset I and II
36	Bitumen (ATI & Waste Chem)
37	Chem-Nuclear cement
38	Hittman grout
39	Petroset I and II
40	Safe-T-Set
48	Stock Equipment cement
49	Westinghouse - Hittman cement
51	Dicalite Dicasorb
95	Other sorbent
96	Other solidification media
97	Other stabilization media
98	None required
99	Other

(a) Codes and descriptions extracted from the EG&G Idaho, Inc. database specifications (MUN91). Unassigned codes are not listed.

(b) Sorption includes absorption and adsorption.

On inspection, radionuclide concentrations generated by the database appeared to indicate that smaller waste containers tended to have activity levels that were several orders of magnitude higher than larger ones. However, using 240 randomly selected containers, no distinct trends were observed that would associate increasing waste activity with smaller container sizes (best noted correlation coefficient, $r^2 = 0.054$). This observation implies that the resulting concentrations are an artifact of the waste packaging methods rather than the practices that actually generate waste.

2.2.15 Presence of NORM Radionuclides in the Database

The presence of naturally occurring radionuclides (NORM) in the database reflects the practices of the waste generators. NORM waste may contain uranium, thorium, and their decay products (e.g., radium). Generators, brokers, and disposal site operators are applying the Class A designation to such waste, although they are not identified in 10 CFR 60.55. Since shipping manifest entries are coded into the database at the disposal sites, it is not possible to break out NORM radionuclides from those regulated by the NRC. Accordingly, the sorts conducted with the database inherently include such radionuclides.

2.3 Database Management

A database management program was developed by SC&A, Inc. for accessing, sorting, 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 the shipping manifests. The data thus retrieved are summarized in tables, histograms, and cumulative distribution curves. The program structure uses dBase/Clipper to retrieve the data and perform the sorts. In total, the electronic files that provide the basis for this report consist of 57.8 megabytes of data. The operating program and its supporting files are contained in 29 files consisting of 720.6 kilobytes and 20.5 megabytes of data, respectively. The program and validation process are described in Appendix B.

Data sorts presenting radionuclide concentration distributions are presented at the shipment level for all three sites and all years and at the container level only for Beatty and Richland from 1988 to 1990. In cases where both container- and shipment-level sorts could be conducted, relationships were established between the shipment and container-level data. In this way, data that are limited to the shipment level could be extrapolated to the container level. This approach was used to obtain results with enough data points to generate meaningful histograms and cumulative distributions.

Numerous data sorts were constructed to characterize the concentrations of individual radionuclides in individual types of waste streams by regions and category of waste generators. The radionuclides were selected based on information reported by the disposal sites and technical literature. Sorts were also conducted as a function of disposal site, State or Compact, year, manifest identification number, waste container identification number, broker or generator code, brokered and non-brokered shipments, waste class, waste physical forms, solidification or sorption agents, nuclides, and waste density. For example, the results of a typical analysis is presented in a table or as a histogram showing concentration distributions (i.e., Ci/m^3 and pCi/g) of C-14 contained in animal carcasses shipped in 200 containers by medical waste generators located in the Northwest Compact, from 1988 to 1990.

Statistical analyses were performed for each distribution generated by the sorts using standard descriptive methods (PRE89). The statistical information shown on each output includes the range of radionuclide concentrations at the 1st, 10th, 25th, 50th, 75th, 90th, and 99th percentile. The histograms provide additional statistical parameters, including average concentrations, average and standard deviations, skewness, kurtosis, and the number of data points characterizing the concentration range of each nuclide.

Radionuclide concentration distributions are provided according to waste volume, which reflect how the concentration distributions differ for varying container and shipment sizes. At the shipment level, these intervals are < 10; >10 and <50; >50 and <100; >100 and <500; >500 and <1,000; and >1,000 cubic feet. At the container level, the intervals include <1; >1 and <5; >5 and <10; >10 and <50; >50 and <100, and >100 cubic feet. The use of these intervals reflects reporting practices and container usage, rather than an arbitrary selection of intervals.

For data with less than 100 points, the 1st and 99th percentile are replaced with the observed minimum and maximum values. Histograms and cumulative distribution curves are based on data sets with a minimum number of 30 points. This approach was used when generating radionuclide concentration histograms to avoid constructing distributions with too few data points. This constraint does not restrict the retrieval and analysis of the data during each search, however. Practices that occur infrequently or involve the generation of rare waste streams are characterized by very few data points, thereby making it difficult to assess their variability over time.

2.4 Organization of this Volume

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 Volumes 4 through 7. The characterization of Class A low-level radioactive waste is contained in this volume and the supporting appendices (Appendices A to K) are provided in Volumes 4 through 7. This volume contains introductory material, which describes the purpose and scope of the report, its organization, and the methods used to acquire, compile, and display the data. Chapter 2 describes the technical approach used to compile and display the database. In addition, a discussion is provided addressing some of the major limitations associated with the database and resulting characterizations.

Following the introduction and this chapter, the next five chapters summarize waste management practices of the major categories of waste generators, i.e., academic, government, industrial, medical, and utility. A final chapter is devoted strictly to waste brokers and processors. These categories are based on the designations defined by the shipping manifests. However, it will become apparent that the practices that result in waste generation, waste streams, radionuclide compositions, and concentrations produced by the different categories of generators have a lot in common. For example, academic, government, industrial, and medical waste generators all produce biomedical waste with similar characteristics. For this reason, some of the information provided in each chapter is repetitive. Cross-referencing is used to minimize the repetition.

Each chapter begins with a description of the various practices that result in the generation of low-level waste in that category, followed by summaries of the unbrokered waste shipments. The discussion of the unbrokered waste shipments consists of summaries of container- and shipment-level data. The container-level data are sufficiently detailed to allow the generation of radionuclide concentration distributions sorted by waste streams and Compacts or States. However, only a small <u>fraction</u> of the waste shipments offer container-level data.

The discussion of the container-level data is followed by a discussion of the shipment-level data. Also provided are summaries of radionuclide concentration distributions at the shipment level, sorted by regions. The shipment level data are limited because it is not possible to sort according to waste streams. However, the shipment level data have the advantage that all unbrokered waste shipped for disposal can be accessed.

For each category of generators, the next section describes the typical waste generators that make up the category. Data are provided on the types and quantities of waste shipped per waste generator, as opposed to the preceding sections, which characterize the types and quantities of waste shipped by the category as a whole.

This section also refers the reader to the appendices listing locations of the principal waste generators in each category and the demographic characteristics in the vicinity of the waste generators. For some Compacts or States, the information could not be obtained, however. Appendix G presents the details.

Following the discussion of each category of waste generator, a separate chapter is devoted to brokered waste. Each brokered shipment is comprised of waste packages from one or more generators, and, like direct shipments, container- or shipment-level information is contained in the database. However, unlike the direct shipment data, it is impossible to sort brokered data at both the shipment and container level. It is for this reason that brokered data are not included in the chapters addressing each category of waste generator.

This volume of the report is supported by 11 appendices (Appendices A through K). Appendix A contains samples of the waste manifest forms that are ultimately the source of all of the data provided here, and Appendix B describes the database management system used to access, sort, and display the data.

The remaining appendices (C through K) contain tables and graphs presenting primarily radionuclide concentration distributions in the principal waste streams associated with each category of waste generator and Compact or State. The appendices are intended to be used as look-up tables to obtain specific information regarding individual waste streams and how they vary according to category of waste generators and regions.

As discussed in Section 2.2, the database has several limitations, which required that the appendices be organized according to a structure similar to that presented in Figure 2-1. The appendices provide data sorts for all waste generator categories, a broad range of waste streams, and by Compact and unaffiliated State. Not every combination and permutation is provided due to the inherent limitations of the database and the enormous output that would be generated.

Appendices L through P provide supporting information for Volume 3, addressing a characterization of methods and facilities being used to treat and dispose of non-radioactive waste under Subparts C and D of the Resource Conservation and Recovery Act. This information includes a list of disposal options, locations of processing and disposal facilities, and descriptions of the characteristics of such processing and disposal facilities.

The following describes the information contained in Appendices C through P.

Appendix C - Non-Brokered, Non-Utility, Container-level Data Sorted According to Compact/State, Category of Waste Generator, and Waste Streams

Appendix C presents data sorts at the container level for non-brokered, non-utility waste (i.e., database (2) in Figure 2-1). As discussed above, container-level data are available only for shipments to Beatty and Richland from 1988 to 1990, and, as such, represent only a small fraction of the data.

The tables in Appendix C present concentration distributions for a large number of radionuclides according to (1) Compact and unaffiliated State, (2) category of waste generator (except utility, which is addressed in Appendix I), and (3) waste streams. The tables provide detailed radionuclide concentration distributions for the following sorts:

Compact/State	Category	Waste Streams	Table
Northwest	Government	Solidified Resins-Cement Dry Solid Solidified Liquids-Cement Non-compacted DAW Non-cartridge Filter Media	C-1
	Academic	Absorbed Aqueous Liquid Animal Carcasses in Lime Dry Solid Compacted DAW	C-2
	Industrial	Dry Solid Sorbed Aqueous Liquid Non-compacted DAW Dewatered Resins Animal Carcasses in Lime Solidified Liquids	C-3
Rocky Mountain	Academic	Absorbed Aqueous Liquid Animal Carcasses in Lime Compacted DAW	C-4
	Industrial	Dry Solid Non-compacted DAW Biological	C-5

Compact/State	Category	Waste Streams	Table
Central	Industrial	Non-compacted DAW Compacted DAW-Cement Dry Solid Solidified Oil-Cement Solidified Resins-Cement Sorbed Aqueous Liquid	C-6
Midwest	Medical	Absorbed Aqueous Liquid Animal Carcasses in Lime Dry Solid Non-compacted DAW	C-7
	Industrial	Dry Solid Non-compacted DAW Solidified Oil	C-8
Central Midwest	Industrial	Dry Solid Solidified Oil	C-9
Southeast	Medical	Dry Solid	C-10
	Industrial	Non-compacted DAW Solidified Oil Other	C-11
Northeast	Industrial	Dry Solid Solidified Resins Solidified Oil Non-compacted DAW	C-12
Appalachian	Industrial	Compacted DAW Non-compacted DAW Solidified Liquids Dry Solid	C-13
Southwest	Academic	Dry Solid Activated Reactor Hardware and Concrete	C-14
	Government	Non-compacted DAW Evaporator Bottoms Solidified Resins Compacted DAW Solidified Liquids Dry Solid Non-cartridge Filter Media	C-15

Compact/State	Category	Waste Streams	Table
	Industrial	Dry Solid Compacted DAW Non-compacted DAW Solidified Liquid Sorbed Aqueous Liquid Cartridge Filter Media-Cement Solidified Oil Dewatered Resins	C-16
Massachusetts	Industrial	Dry Solid Non-compacted DAW Evaporator Bottoms Sorbed Aqueous Liquids Solidified Liquids Solidified Oil	C-17
	Government	Solidified Liquids Dry Solids	C-18
New Hampshire	Industrial	Dry Solid	C-19
New York	Industrial	Dry Solid	C-20
Texas	Industrial	Dry Solid Non-compacted DAW Compacted DAW Cartridge Filter Media Solidified Liquid-Cement	C-21
	Government	Solidified Liquid-Cement	C-22

Appendix D - Non-Brokered, Non-Utility, Container-level Data Sorted According to Category of Waste Generator and Waste Streams

Appendix D presents graphs depicting concentration distributions of individual radionuclides. The graphs were constructed from non-utility container-level data for waste shipped to Beatty and Richland from 1988 to 1990. The type of information is similar to that in Appendix C, except that the data are not categorized according to Compact or unaffiliated State and are presented in graphical form. The following figures are provided in Appendix D:

(1) Non-brokered waste shipped from medical facilities as dry solid waste. Concentration distributions are provided for Ra-226 only.

(2) Non-brokered waste shipped from academic facilities as compacted DAW. Concentration distributions are provided for 19 radionuclides.

(3) Non-brokered waste shipped from medical facilities as absorbed aqueous liquids. Concentration distributions are provided for 14 radionuclides.

(4) Non-brokered waste shipped from academic facilities as dry solid waste. Concentration distributions are provided for 14 radionuclides.

(5) Non-brokered waste shipped from academic facilities as absorbed aqueous liquid waste. Concentration distributions are provided for 13 radionuclides.

(6) Non-brokered waste shipped from academic facilities as solidified liquid waste. Concentration distributions are provided for 11 radionuclides.

(7) Non-brokered waste shipped from all categories of facilities as animal carcasses in lime and sorbents. Concentration distributions are provided for 16 radionuclides.

Appendix E - Non-Brokered, Non-Utility Shipment-level Data Sorted by Compact Region and State

Appendix E presents non-brokered, shipment-level data sorts presenting concentration distributions for several radionuclides contained in Class A biomedical waste. This appendix is similar to Appendix C, except that nuclide concentration distributions are aggregated over the entire shipment and the data are not sorted by waste streams. As a result, the level of precision is less than that provided in Appendix C. However, all direct shipment-level data from 1986 to 1990 for all disposal sites are accessed, as opposed to a smaller subset. The following data sorts are provided in Appendix E:

Compact/State	Category		Table
Northwest	Government	All Class A Biomedical	E-1
	Medical	All Class A Biomedical	E-2
	Academic	All Class A Biomedical	E-3
	Industrial	All Class A Biomedical	E-4

Compact/State	Category		Table
Rocky Mountain	Academic	All Class A Biomedical	E-5
	Industrial	All Class A Biomedical	E-6
Central	Government	All Class A Biomedical	E-7
	Academic	All Class A Biomedical	E-8
	Industrial	All Class A Biomedical	E-9
Midwest	Government	All Class A Biomedical	E-10
	Academic	All Class A Biomedical	E-11
	Medical	All Class A Biomedical	E-12
	Industrial	All Class A Biomedical	E-13
Central Midwest	Government	All Class A Biomedical	E-14
	Academic	All Class A Biomedical	E-15
	Medical	All Class A Biomedical	E-16
	Industrial	All Class A Biomedical	E-17
Southeast	Government	All Class A Biomedical	E-18
	Academic	All Class A Biomedical	E-19
	Medical	All Class A Biomedical	E-20
	Industrial	All Class A Biomedical	E-21
Northeast	Government	All Class A Biomedical	E-22
	Academic	All Class A Biomedical	E-23
	Medical	All Class A Biomedical	E-24
	Industrial	All Class A Biomedical	E-25
Appalachian	Government	All Class A Biomedical	E-26
	Academic	All Class A Biomedical	E-27
	Medical	All Class A Biomedical	E-28
	Industrial	All Class A Biomedical	E-29

Appendix E listing, Cont'd:

Compact/State	Category		Table
Southwest	Government	All Class A Biomedical	E-30
	Academic	All Class A Biomedical	E-31
	Medical	All Class A Biomedical	E-32
	Industrial	All Class A Biomedical	E-33
District of Columbia	Academic	All Class A Biomedical	E-34
	Medical	All Class A Biomedical	E-35
	Industrial	All Class A Biomedical	E-36
Maine	Government	All Class A Biomedical	E-37
	Academic	All Class A Biomedical	E-38
	Industrial	All Class A Biomedical	E-39
Massachusetts	Government	All Class A Biomedical	E-40
	Academic	All Class A Biomedical	E-41
	Medical	All Class A Biomedical	E-42
	Industrial	All Class A Biomedical	E-43
New Hampshire	Academic	All Class A Biomedical	E-44
	Industrial	All Class A Biomedical	E-45
New York	Government	All Class A Biomedical	E-46
	Academic	All Class A Biomedical	E-47
	Medical	All Class A Biomedical	E-48
	Industrial	All Class A Biomedical	E-49
Rhode Island	Government	All Class A Biomedical	E-50
	Academic	All Class A Biomedical	E-51
	Medical	All Class A Biomedical	E-52
	Industrial	All Class A Biomedical	E-53

Appendix E listing, Cont'd:

Compact/State	Category		Table
Texas	Government	All Class A Biomedical	E-54
	Industrial	All Class A Biomedical	E-55
Vermont	Academic	All Class A Biomedical	E-56
	Medical	All Class A Biomedical	E-57
	Industrial	All Class A Biomedical	E-58

<u>Appendix F</u> - Shipment-level Data, Non-Brokered Waste

Appendix F graphically presents shipment-level data for all non-brokered, Class A waste shipments from 1986 to 1990 (not including utility waste, which is addressed in Appendix I) as a function of Compact and unaffiliated State and by category of waste generators. The data are not sorted by waste stream. The sorts are provided in two forms based on the availability of the data:

(1) For each sort, the displays are limited to distributions depicting the variability of the total volume (cubic meters) and total curie inventory (not by nuclide) per shipment.

(2) For each sort, the displays include distributions depicting the variability of the total volume (cubic meters) and total curie inventory (not by isotope) per shipment and also the variability of the individual radionuclide concentration per shipment.

<u>Appendix G</u> - Location of Major Waste Generators, Population Distributions, and Listing of Major Waste Brokers and Processors

Appendix G-1 presents the geographic locations of the major waste generators for each of the nine Compacts and nine unaffiliated States. The locations of the major waste generators are identified by city, county, and state rather than by mailing address. Such locations, however, may not necessarily represent the physical location where wastes are actually being generated. Similarly, some facilities may have more than one location identified under the same NRC or Agreement State license. Consequently, it is not always possible to identify the true origin of the waste. Some Compacts or States provide this information in their yearly survey reports by identifying specific locations. Other states, however, do not provide this information, since some generators deem this type of data to be confidential or sensitive business information.

Demographic data at the county level of each waste generator are provided in Appendix G-2. Population data were obtained from the Bureau of Census in an electronic format from the 1990 census (DOC92). The data files, contained in 11 diskettes, were sorted using dBase to extract population data by state and county. Population data were derived for each of the nine Compacts and nine unaffiliated States.

Appendix G-3 presents a listing of the major waste brokers and processors. This listing is not an endorsement of the services provided by these firms.

Appendix H - Shipment-level Analysis of Fuel Fabrication Facilities

Fuel fabrication facilities are a subset of the industrial sector requiring separate treatment due to the unique nature of the practice. Appendix H presents shipment-level sorts and radionuclide concentration distributions for shipments from 11 states with fuel fabrication facilities. The results include:

State	Exhibit	State	Exhibit
Connecticut	H-1	Oklahoma	H-7
Pennsylvania	H-2	Missouri	H-8
Virginia	H-3	Tennessee	H-9
North Carolina	H-4	Washington	H-10
South Carolina	H-5	California	H-11
Illinois	H-6		

Radionuclide concentration distributions and shipment mass distributions for source and special nuclear material are provided in tables and graphs.

Appendix I - Non-Brokered, Container-level Analysis of Utility Waste

Appendix I presents non-brokered, container-level radionuclide concentration distributions sorted by waste streams. Since the data are at the container level, they include only shipments to Richland and Beatty from 1988 to 1990.

The data are presented in tables and graphs. The data sorts include:

Waste Streams	Year	Exhibit
Dry Solid	1989	I-1
Solidified Liquids	1989	I-2
Dewatered Resins	1989	I-3
Solidified Resins	1989	I-4
Evaporator Bottoms	1989	I-5
Compacted DAW	1989	I-6
Non-compacted DAW	1989	I-7
Non-cartridge Filter	1989	I-8
Solidified Oils	1989	I-9

Appendix J - Non-Brokered, Shipment-level Analysis of Utility Waste

Appendix J is similar to Appendix I, except that the data are provided at the shipment level. The data are sorted according to waste disposal site, as follows:

Site	Year
Barnwell	1989
Richland	1989

In addition, sorts are provided for selected regions for 1986 to 1990 providing the distributions of the volume and total curie inventory per shipment.

Appendix K - Container-level Analysis of Brokered Waste

Appendix K presents selected tabular and graphical distributions of radionuclide concentrations sorted by waste streams. As noted in Section 2.2, brokered waste data cannot be sorted by waste generator sectors. The sorts include:

Waste Streams	Region/State	Exhibit
Non-compacted DAW	All	K-1
Compacted DAW	Illinois 1989	K-2
Dewatered Resins	All	K-3
Solidified Resins	All	K-4
Sorbed Aqueous Liquids	Illinois 1989	K-5
Solidified Liquids	Illinois 1989	K-6

Appendix L

Appendix L presents population data around RCRA Subparts C and D facilities.

Appendix M

Appendix M summarizes the results of a 1986 survey of municipal solid waste landfills.

Appendix N

Appendix N presents a summary of commentaries about landfill disposal capacity in the United States.

Appendix O

Appendix O presents a listing of municipal solid waste landfills based on 1992 survey.

Appendix P

Appendix P presents a cross-reference list of the geographical locations of treatment and disposal facilities covered in Sections 9 and 10 of Volume 3.

3.0 ACADEMIC INSTITUTIONS

3.1 Introduction

Academic institutions include universities, colleges, and other specialized teaching facilities using radioactive materials. Some academic institutions may be associated with medical centers, hospitals, or clinics. Academic institutions may be run privately or by a federal or state agency. Academic waste generators are involved in diverse types of educational activities, such as medical training (including veterinary), medical research, drug development and testing, health care services, industrial research, materials testing, organic and inorganic chemistry, geological exploration, and basic and applied research in other scientific disciplines. Academic facilities are licensed by the Nuclear Regulatory Commission (NRC) and Agreement States.

Academic institutions generate low-level waste through the use of radioactive materials produced by research reactors, particle accelerators, and supplied by radio-chemical laboratories. It is common practice for academic institutions to secure commercial services, through brokers, for waste disposal, especially those that generate small volumes of waste. Brokers typically provide shipping containers, packaging materials, shipping documents, etc., and arrange for transportation and disposal.

This section characterizes low-level waste generated by academic institutions. Most of the discussions and the data summaries also apply to the medical sector. In reviewing the information presented in this section, the reader is alerted to the fact that the database incorporates some inherent limitations that must be recognized to properly interpret the results. Some of these limitations are associated with generator disposal practices, while others are due to differences in how the data are coded and maintained by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

3.2 Characterization of Academic Waste Generator Activities

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 technical and scientific fields.

Biomedical research involves the use of radioactive materials in bio-chemical, bio-physical, and physiological investigations. Such investigations involve the use of radioactive tracers introduced into tissue samples, cell cultures, animals, and human subjects to study drug metabolism, bio-kinetics, and reaction of subjects to varying doses. Nuclear medicine involves administering discrete amounts of radioactive materials for the purpose of assessing organ functions and uptake (e.g., thyroid); imaging the distribution of a tracer within an organ (e.g., detecting the presence of a tumor); estimating the volume and density of tissues in organs (e.g., blood cell and plasma volumes); and measuring the presence of biological components in tissue samples (e.g., protein, steroid, or hormone levels).

Radiopharmaceutical products are available in a variety of kits (e.g., as unit-dose, radio-immunological assay kits [RIA]), which contain all the necessary components for administration (NEN91, ICN91, AME91). Such kits contain varying levels of radioactivity, from very small amounts (e.g., up to several hundred microcuries) to relatively large quantities (e.g., several hundred millicuries). Other kits, however, give the end-user the capability to prepare administrative doses by using a dispensing unit (e.g., a Mo-99/Tc-99m generator). Generators usually contain relatively larger quantities of radioactivity (e.g., from several hundred millicuries to a few curies). For some medical procedures, e.g., positron emission tomography, short-lived nuclides are produced with the use of a cyclotron.

Other sources of radioactivity include sealed sources, which are incorporated in equipment or instrumentation or are used as density or level gauges, irradiation devices, static eliminators, etc. Depending upon the application, such research activities may generate relatively little or no waste at all. At times, sealed sources may be disposed of as radioactive waste or returned to the supplier for disposal.

3.2.1 Waste Streams and Forms

Academic facilities generate a wide spectrum of waste. Such waste include solids, biological, compressible and non-compressible materials, and aqueous and organic liquids. Some liquids may be solidified or immobilized in absorption media. The following subsections present an overview of the primary types and forms of waste routinely generated by the academic or biomedical sector (NRC81a, NRC81b, NRC82, NRC83a, NRC83b, NRC86a, DOE87, DOE90a, EPA88). Much of the information and data presented below also apply to the characterizations of other types of waste generators involved in providing health care services, conducting medical research, and radio-pharmaceutical production. Such generators include medical and government institutions and industrial facilities.

Throughout this report, a key parameter used to characterize low-level waste is its physical and chemical form. The concern regarding waste form stems from NRC requirements and guidelines that are "intended to facilitate handling at the disposal site and provide protection of health and safety of personnel at the disposal site." Waste generators are disposing Class A waste using stabilization media even though 10 CFR Parts 61.55 and 61.56 do not require it, unless it is commingled with Class B or C waste. Disposal site operators have followed through by identifying and coding such waste as "stable" or "unstable." The shipping manifests list the codes of various types of solidification and sorbent agents. Section 2.2, Table 2-7 lists a number of waste streams and absorption and solidification media that are authorized by the Beatty and Richland disposal sites.

Solid Waste

Solid waste includes absorbent pads, paper towels, cloth, plastic and glass bottles, syringes, pipettes, plastic trays, empty product or stock solution containers, spent resin columns and filters, pH probes, centrifuge and test tubes, beakers and graduated cylinders, cell culture dishes and flasks, plastic and glass tubing, and miscellaneous disposable labware supplies. Protective clothing items are also disposed of as waste and include gloves, lab coats, coveralls, shoe and head covers, and spent-filter respirator cartridges. Laboratory equipment is also disposed of as waste. Such items may consist of tube storage racks, dispensing apparatus, hot plates, vacuum pumps, mixers, hardware, components, and parts from centrifuges, cell dispensers, glove boxes, spent HEPA and charcoal filters, etc.

Liquid Scintillation Waste

Liquid scintillation waste consists of regulated and de-regulated spent organic fluids contained in plastic or glass vials. Liquid scintillation fluids, also known as "cocktails," primarily consist of toluene, xylene, benzene, dioxane, trimethylbenzene, and cylohexane (NRC80a, NRC86b, NRC92). These organic compounds are found, at varying concentrations, in both aqueous and non-aqueous forms. Spent cocktails also contain trace levels of research compounds, in addition to the radioactivity.

The disposal of deregulated liquid scintillation waste is authorized under existing federal regulations under Title 10, Part 20.306, and their counterparts under Agreement State regulations (CFR90). Such regulations apply only to H-3 and C-14 in concentrations not exceeding 0.05 uCi/mL. These regulations do not exempt the facility from complying with any other federal, state, and local regulations governing toxic or hazardous properties of spent liquid scintillation waste. Current practices favor the use of incineration for the disposal of regulated and deregulated liquid scintillation cocktails. Water soluble base cocktails are being used more frequently as they are easier to handle and dispose of than organic ones.

Aqueous Liquids

Aqueous liquid waste consists of soluble compounds present in water solutions. Such solutions are generated during the washing or rinsing of laboratory equipment, while flushing dispensing units, by analytical equipment that segregate radioactive from non-radioactive fluid streams, when collecting initial solution baths or first rinses from electrophoresis units, etc. Typically, very dilute aqueous waste are drained or flushed into sanitary or chemical drain systems. Some types of aqueous waste are at times stabilized using solidification agents, such as concrete or other cementitious materials. Patient excreta are usually flushed into sanitary systems or may be collected and held for decay if activity levels are too high. The NRC, under 10 CFR 20.303(d), provides the exemption to release patient excreta into sanitary sewers. Such practices do not exempt the facility from complying with any other federal, state, and local regulations governing toxic or hazardous properties of such waste.

Organic Liquids

Organic liquids have origins similar to those of aqueous waste, except that the solute consists of solvents, such as alcohols, aldehydes, ketones, organic acids, acetone, acetonitrile, benzene, chloroform, diethyl ether, ethyl acetate, hexane, and toluene (NRC92). Organic liquids, if soluble, may be disposed of in sanitary or chemical drain systems. As noted earlier, such practices do not exempt the facility from complying with any other federal, state, and local regulations governing their toxic or hazardous properties. Organic liquids are also, at times, solidified using techniques similar to those used for aqueous waste.

Biological Waste

Biological waste consists of animal carcasses, tissues, cell cultures, and animal bedding and excreta. Biological waste may consist of an entire animal or only certain parts or organs. Biological waste usually are disposed of in drums containing lime. As with spent liquid scintillation fluids, the disposal of biological waste is also authorized under existing federal regulations under Title 10, Part 20.306, or their counterparts under Agreement State regulations (CFR90). Such regulations apply only to H-3 and C-14 in concentrations not exceeding 0.05 uCi/g. These regulations do not exempt the facility from complying with any other federal, state, and local regulations governing the disposal of potentially pathological or hazardous properties of biological waste.

Stabilized Waste

Some waste forms are stabilized by incorporating them into solidification or absorbent materials. Such waste are generally classified as "stabilized or sorbed" waste. However, the use of a solidification or absorbent agent does not by itself ensure stabilization. The NRC presents specific requirements under 10 CFR 61.56 and the Technical Position on Waste Form (NRC91). In using such agents, liquid waste or spent ion-exchange resins are mixed with cement and allowed to cure into the shipping container. Cement is also used to encase radioactive components or sources for shielding purposes and to provide additional structural integrity. In addition to cement, there are several other types of solidification agents currently authorized by the three disposal sites (See Section 2.2, Table 2-7). Absorbent materials are used to retain small amounts of liquid held in containers or to retain residual liquids dispersed throughout the waste volume. The primary purpose of absorbent materials is to prevent the pooling of liquids at the bottom of waste containers. Absorbent materials are used when disposing of animal litters, animal carcasses, damp paper towels, absorbent pads, and with items containing residual liquids, e.g., test tubes, vials, or syringes. The disposal sites have established limits on the presence of free-standing liquids in such waste.

Gaseous Waste

Gaseous waste is most often generated when conducting lung ventilation studies. Noble gases (Xe-127 and Xe-133), which are used during such studies, are either released in the atmosphere or trapped in activated charcoal beds, where they are then allowed to decay. Other forms of gaseous waste include H-3, as water vapors, C-14, as radio-labeled CO_2, and radioiodines.

Other Waste

Facilities may occasionally generate waste volumes (up to several thousand cubic feet) associated with decontamination, decommissioning, or modifications (NRC81c). Such waste includes floor tiles, bench top surfaces, laboratory hoods, glove boxes, exhaust ventilation duct-work and filter housings, and sink, floor drain piping, and traps. Other waste may also include contaminated or activated equipment, hardware, and concrete (NRC83a, NRC83b).

3.2.2 Radionuclides and Volumes of Waste Shipped for Disposal

Academic institutions routinely use a broad spectrum of radionuclides. The selection of a specific radionuclide depends upon the type of research activity or process being considered, methods applied to introduce or administer the radionuclide, and the technique used to measure the outcome of the procedure.

The majority of radionuclides used by academic institutions are produced by research reactors, while short-lived nuclides (e.g., C-11, N-13, F-18, Ga-68, I-123) are made with particle accelerators, such as cyclotrons. Because of the short half-lives, accelerator facilities are typically located near the point of use. Some academic facilities operate their own research or test reactors and accelerators. 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. This listing is based on radionuclides most often cited by the three commercial low-level waste disposal sites (EGG90). A review of the literature, however, indicates that the number of nuclides routinely reported is more extensive (ICR77, NCR82, NCR89b, NRC90, IAE90, ICN91, AME91, NEN91, NIS91). Table 3-1 lists radionuclides reported by academic institutions. This listing captures over 99 percent of the total activity shipped as Class A waste.

Table 3-1 Principal Waste Radionuclides Reported by Academic Institutions

	<24 hours	<7 Days	<100 Days	<1 Year	>1 Year	>100 Years
	Tc-99m	In-111	P-32	Ca-45	H-3	C-14
			S-35	Mn-54	Na-22	Ni-63
			Sc-46	Co-57	Co-60	Tc-99
			Cr-51	Zn-65		
			Sr-85	Se-75		
			Nb-95	Ag-110m		
			Ru-103			
			I-125			
			I-131			
			Ce-141			
			Ir-192			
n=	1	1	11	6	3	3
%=	4.0	4.0	44.0	24.0	12.0	12.0

The waste volumes and activities shipped for disposal by academic generators are shown in Table 3-2. The values include all classes of waste and both brokered and unbrokered shipments. In decreasing order, principal producers of academic waste are the Southwest, Southeast, Midwest, and the Northeast Compacts and the States of New York and Texas. Together, they generate nearly 80% of the waste volume. The balance of the Compacts and States typically generate individually less than five percent each.

Waste activity levels shipped for disposal by academic waste generators from 1986 to 1990 are shown in Table 3-3 (NRC90, DOE90b). A review of Table 3-3 indicates that, depending on the year, academic institutions make up 0.23 to 4.9 percent of the total activity produced by institutional and industrial facilities (waste from nuclear utilities are not included). The activity shipped for disposal for different years ranges from 107 to 2,260 Ci, which peaked in 1988.

3.3 Detailed Characterization of Waste Properties

The detailed characterization of academic low-level waste is based on information obtained from the National Low-Level Waste Management Program database, known as "MIMS." Low-level waste data were made available in electronic files from EG&G Idaho, Inc. for all three disposal sites (MUN90, MUN91). The electronic files contain manifest data at the shipment level for five years, from 1986 to 1990. However, data at the container level are available only for Beatty and Richland from 1988 to 1990. In both cases, the 1990 data reflect information posted by the end of November 1990. This information was supplemented by data obtained through on-line access to the MIMS system and reports. A description of the computer program used in this study, data sorts and analyses, and validation of the database and program are provided in Section 2.0 and Appendix B.

Waste shipped by brokers or waste processors are not included in these analyses because the data available at the container level are aggregated in a manner that precludes sorting according to category of waste generators. Accordingly, brokered waste is addressed in Chapter 8.0 of this report.

3.3.1 Waste Characterization - Container Level

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

Table 3-2 Academic Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 to 1990[(a)]

	Volume		Activity	
Compact/State	Vol. (m^3)	Percent	Act. (Ci)	Percent
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	7,272	---	5,306	---

(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 for 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.

Table 3-3 Yearly Activity and Waste Volumes Generated by the Academic Sector[a]

Year		Academic	Total (Excluding Utilities)
1986	Volume (m^3)	8.15E+2	2.18E+4
	Percent	3.7	100
	Activity (Ci)	1.07E+2	6.32E+4
	Percent	0.69	100
1987	Volume (m^3)	1.34E+3	2.48E+4
	Percent	5.4	100
	Activity (Ci)	1.07E+2	4.98E+4
	Percent	0.23	100
1988	Volume (m^3)	1.25E+3	1.75E+4
	Percent	7.1	100
	Activity (Ci)	2.26E+3	4.62E+4
	Percent	4.9	100
1989	Volume (m^3)	1.84E+3	2.21E+4
	Percent	8.3	100
	Activity (Ci)	1.94E+3	1.41E+5
	Percent	1.3	100
1990	Volume (m^3)	1.38E+3	1.42E+4
	Percent	9.7	100
	Activity (Ci)	1.09E+3	1.14E+5
	Percent	1.0	100
Total			
	Volume (m^3)	6.63E+3	1.00E+5
	Percent	6.6	100
	Activity (Ci)	5.50E+3	4.18E+5
	Percent	1.3	100

(a) Data extracted from NUREG-1418 (NRC90), EG&G MIMS On-Line Service, and the 1989 State-by-State Assessment (EGG90). 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.

- 19 shipping manifests
- 2,452 container records
- 297 cubic meters of waste
- 156,500 kg of waste, 0.53 g/cm^3 average density
- 23.3 Ci of total activity, 0.08 Ci/m^3

Table 3-3 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered and Classes A, B and C, by academic waste generators from 1988 to 1990 was 4,470 cubic meters and 5,290 Ci, respectively. Accordingly, this search represents nearly seven percent of the volume and about 0.4 percent of the total activity shipped by academic waste generators. The reason that the percentage of the activity captured in the sort is much smaller than that of the volume is because over 95 percent of the activity in low-level waste is contained in Class B and C waste, comprising about 5 percent of the volume. For the same reason, the average gross radionuclide concentration of this sort is about 0.08 Ci/m^3, while the average gross radionuclide concentration in all academic waste (from 1988 to 1990) is nearly 1.2 Ci/m^3.

Appendix C reveals that the container-level data for academic institutions are limited to waste shipped predominantly from the Northwest and Rocky Mountain Compacts and does not include waste from the large academic waste generators located in the East. This is because most of the waste shipped from the eastern United States is handled by brokers and shipped to Barnwell, which does not provide data at the container level. Accordingly, the Class A container-level data available for academic waste may not be representative of all Class A containers. However, the sort has captured the majority of the Class A waste for the Northwest and Rocky Mountain Compacts and is representative of these Compacts. The portion not captured by the sort is the brokered waste.

Exhibit 3-1 presents concentration distributions of the principal radionuclides contained in the 2,452 containers captured by the sort. The results of the search revealed the following concentration distributions for the principal radionuclides:

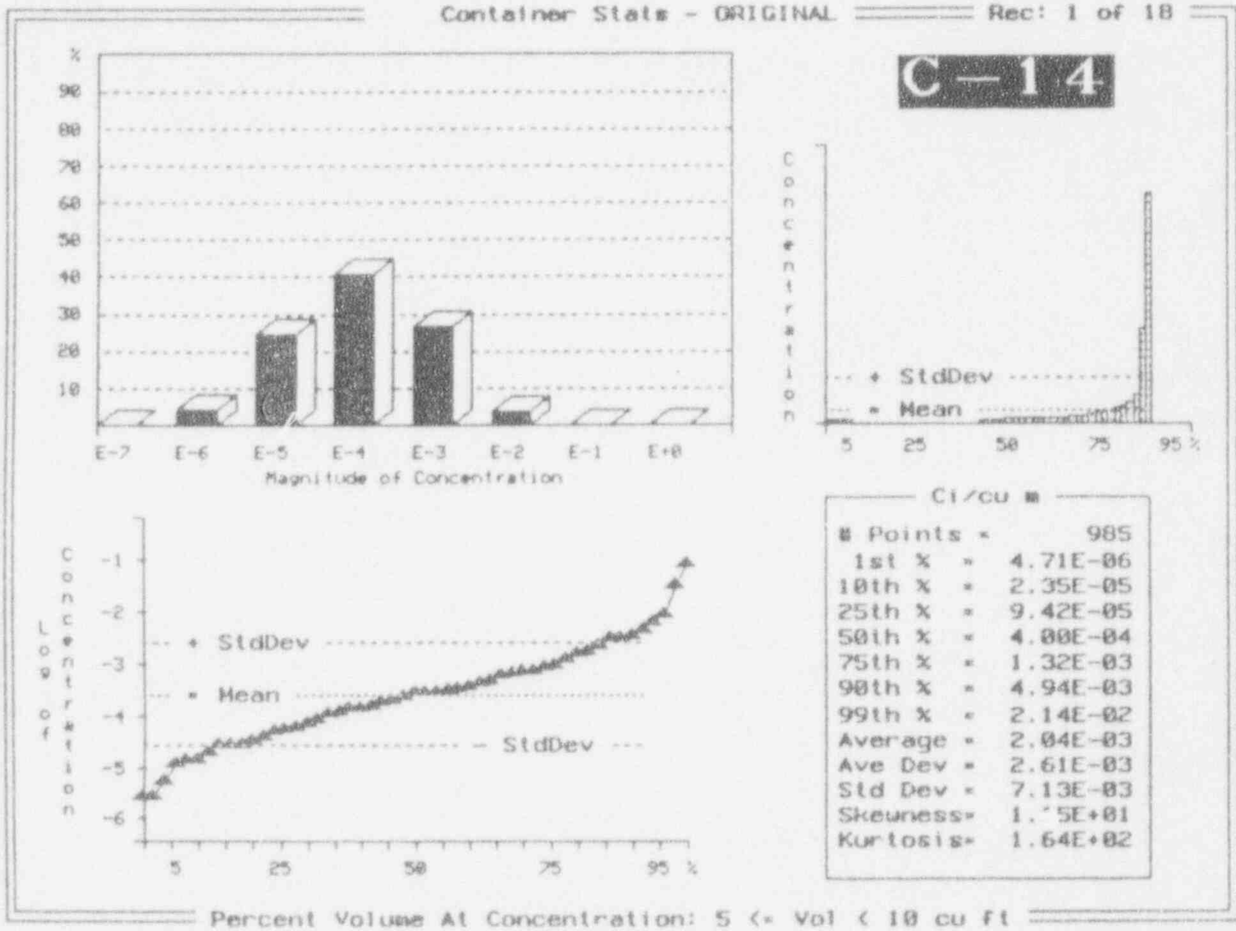
			Concentration (Ci/m^3)					
Radionuclide	Class A Limits (Ci/m^3)	Activity Shipped (Ci)	Median	Average	1%ile	10%ile	90%ile	99%ile
C-14	0.8	5.0E-01	4.0E-04	2.04E-03	4.7E-06	2.35E-05	4.94E-03	2.1E-02
Ca-45	700	7.9E-02	4.2E-04	1.47E-03	4.7E-06	4.24E-05	4.71E-03	1.3E-02
Cr-51	700	1.3E+00	1.9E-03	8.70E-03	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
	Total	2.27E+01						

EXHIBIT 3-1

ACADEMIC WASTE - CONTAINER-LEVEL ANALYSIS

Number of shipping records captured:	19
Number of container records captured:	2,452
Number of isotope records captured:	8,134
Total activity of containers (Ci):	2.33E+01
Total volume of containers (m^3):	2.97E+02
Total weight of containers (kg):	1.57E+05
Total density (g/cm^3):	5.25E-01
Total concentration (Ci/m^3):	7.86E-02
Total concentration (pCi/g):	1.50E+05

Exhibit 3-1 (Continued)



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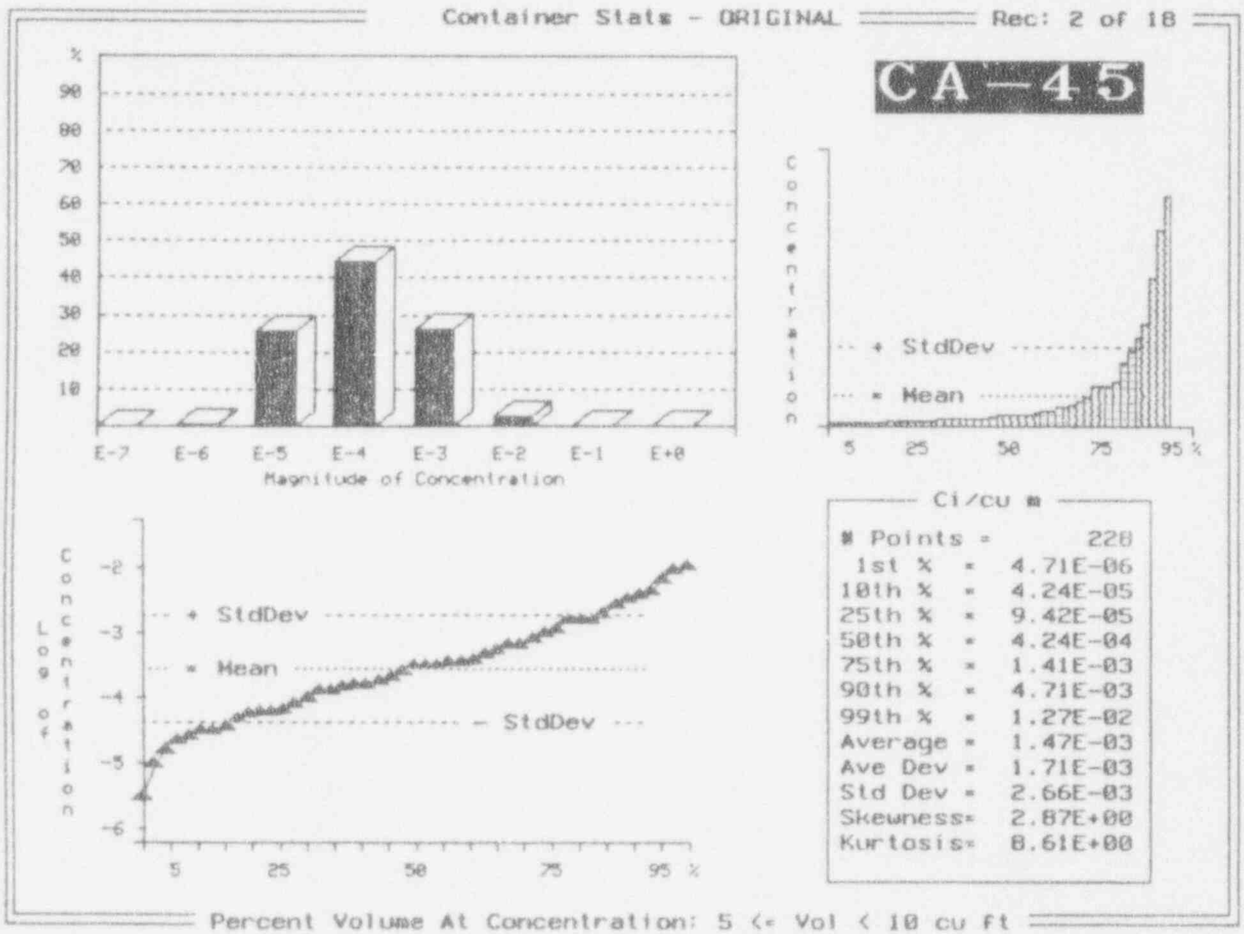

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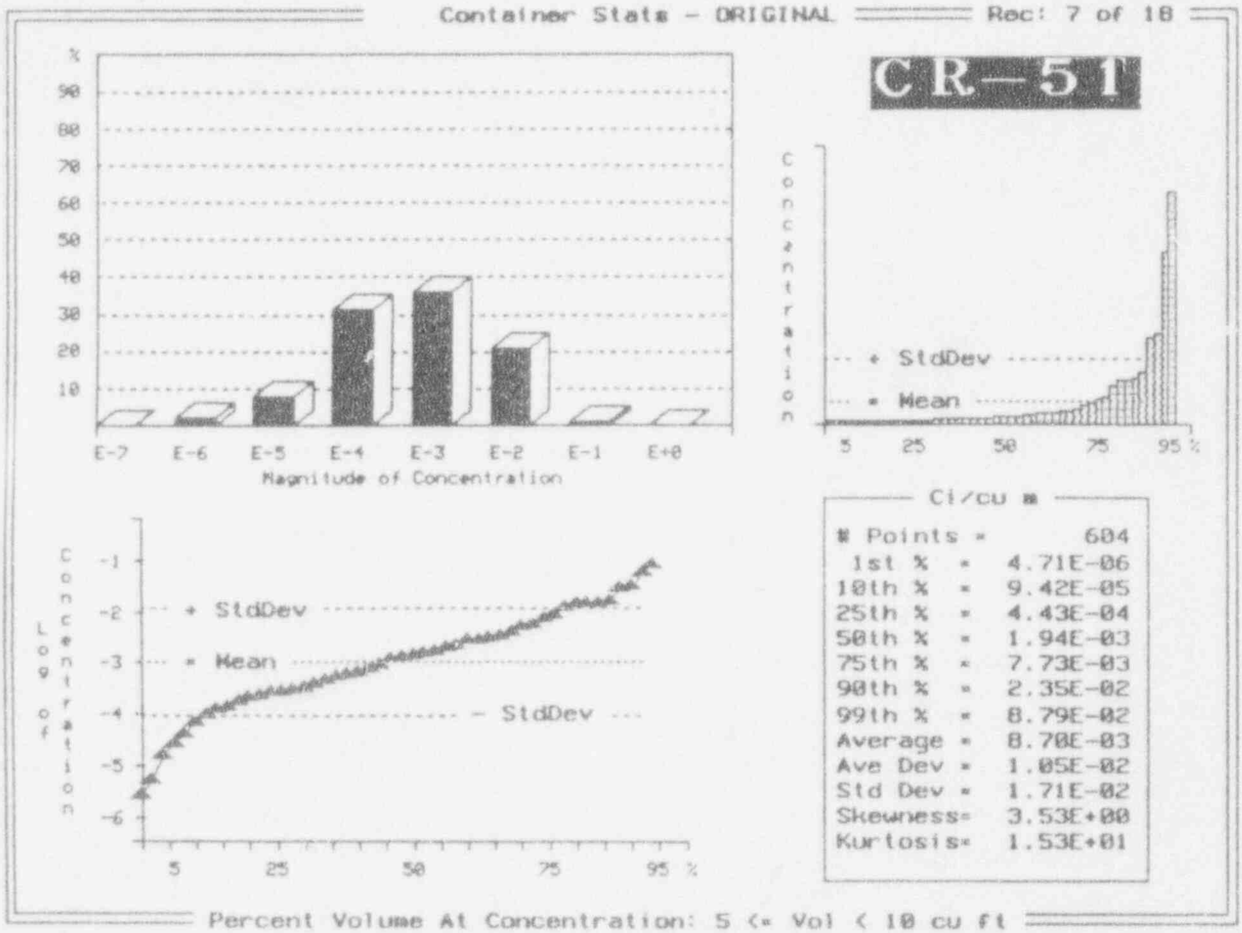

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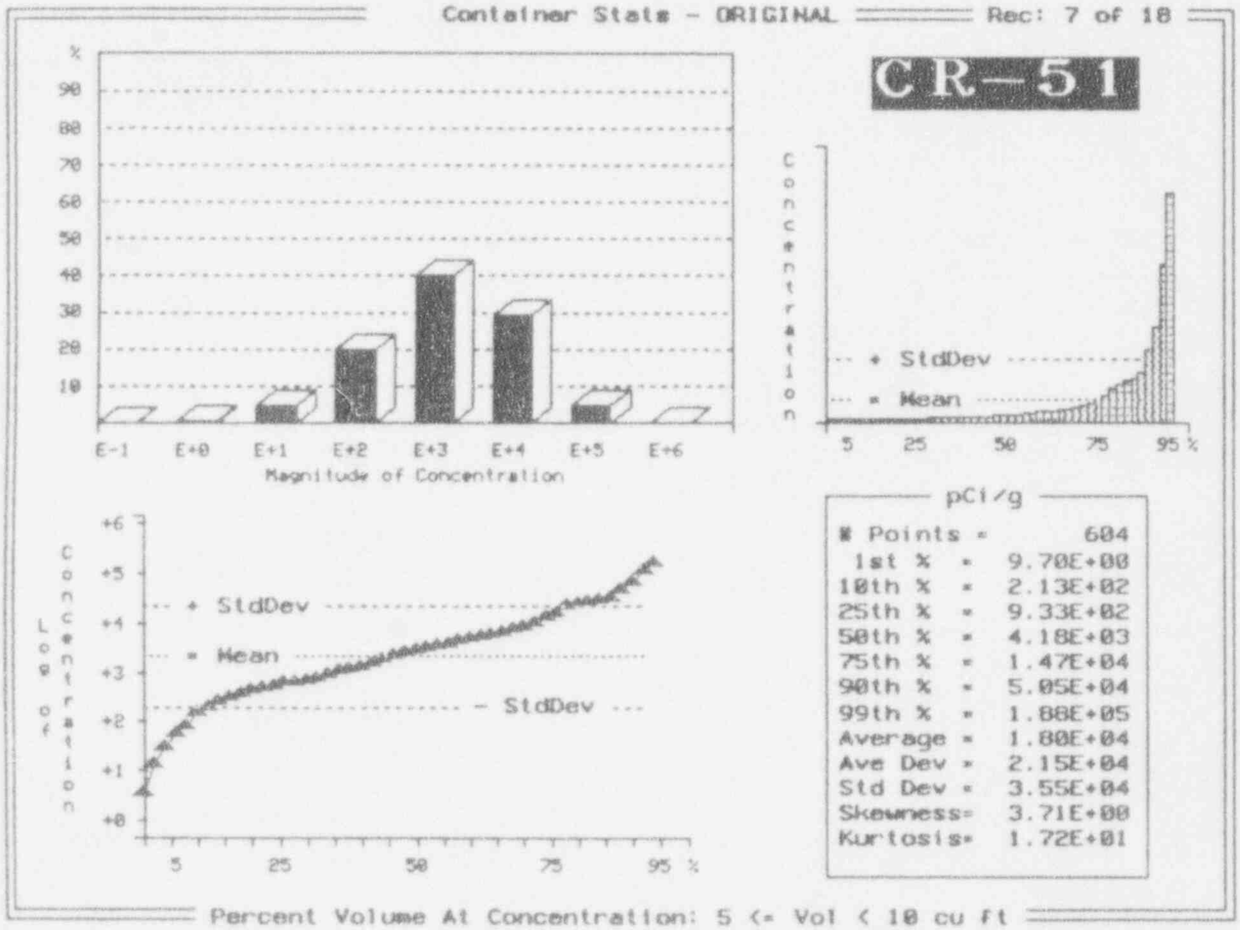

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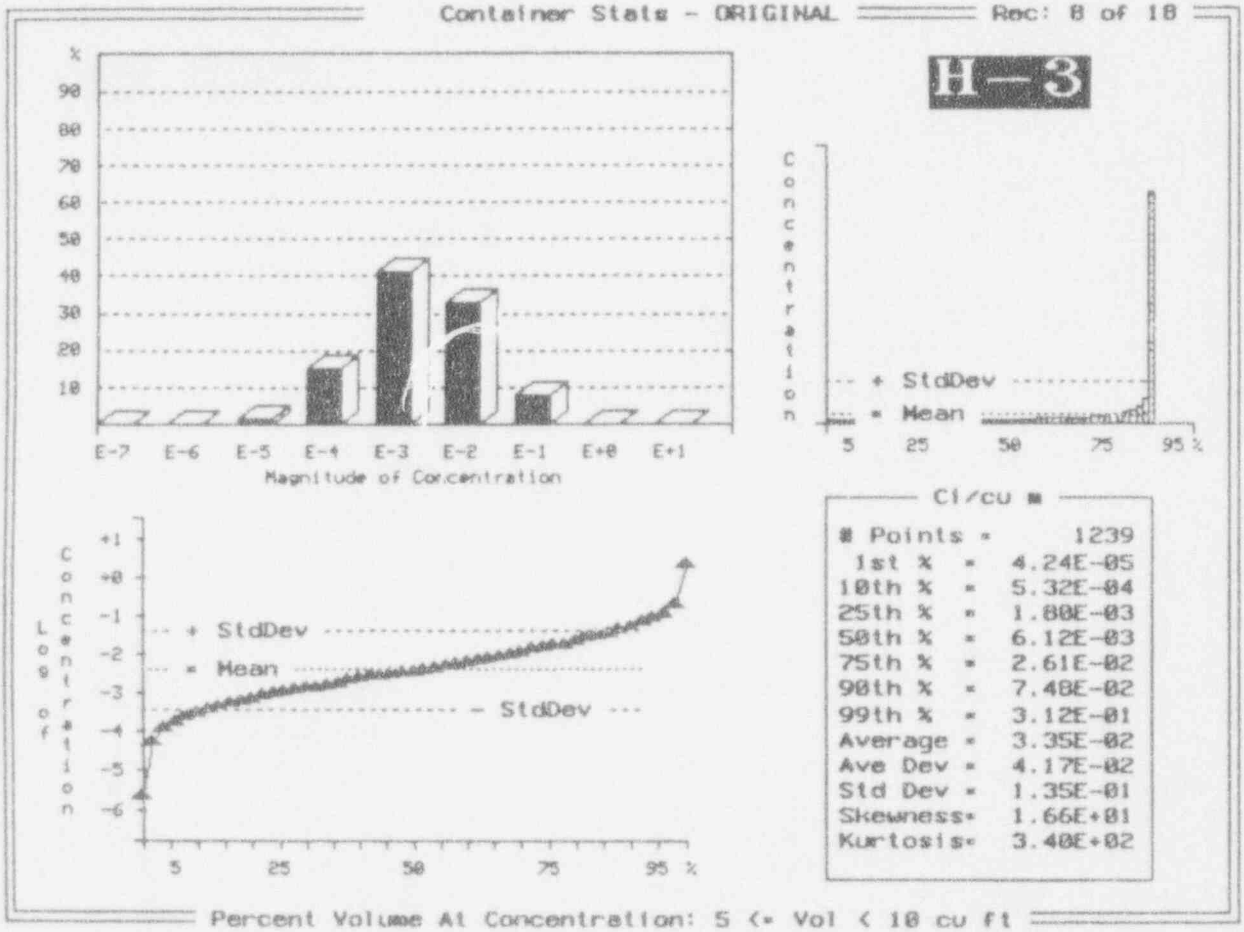

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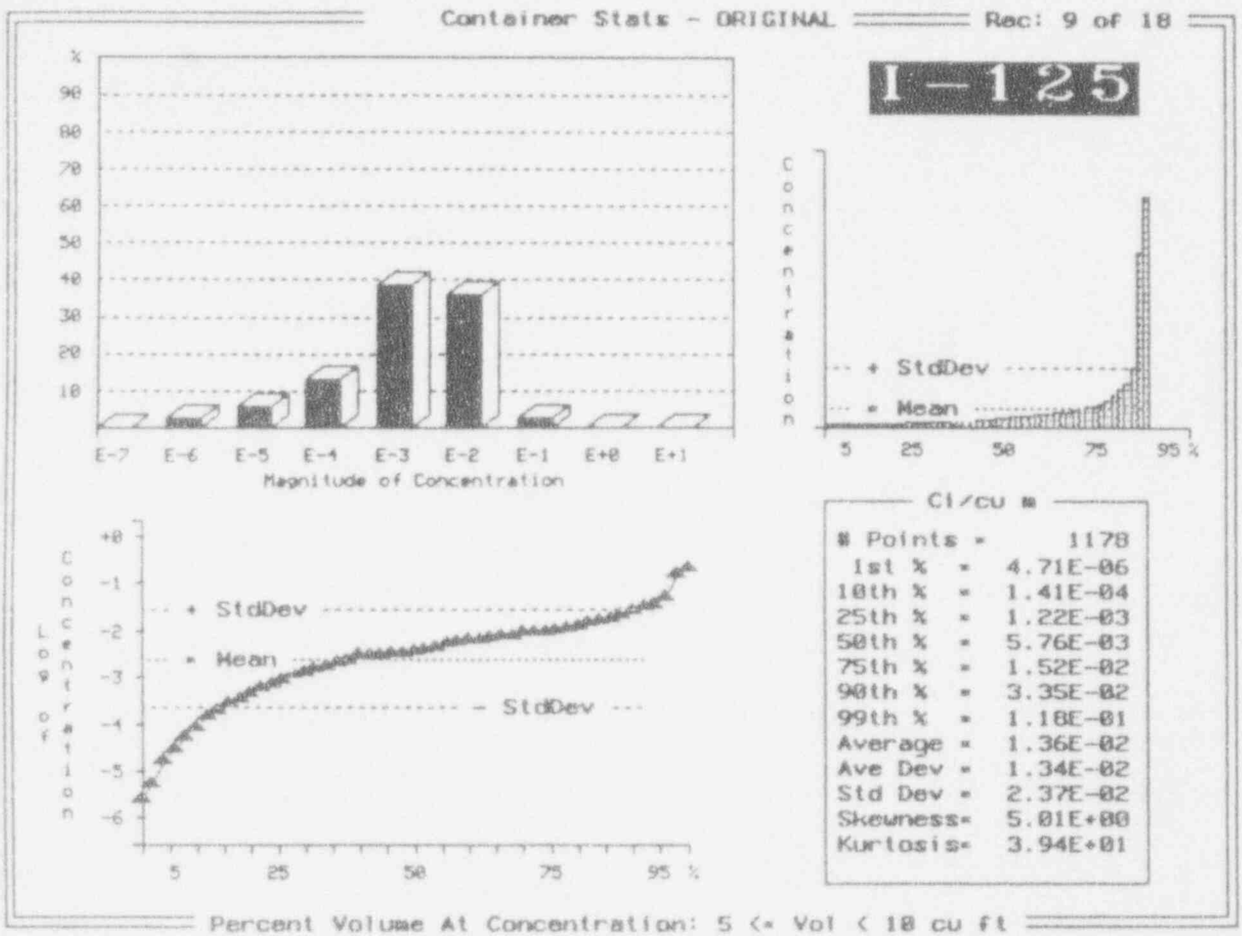

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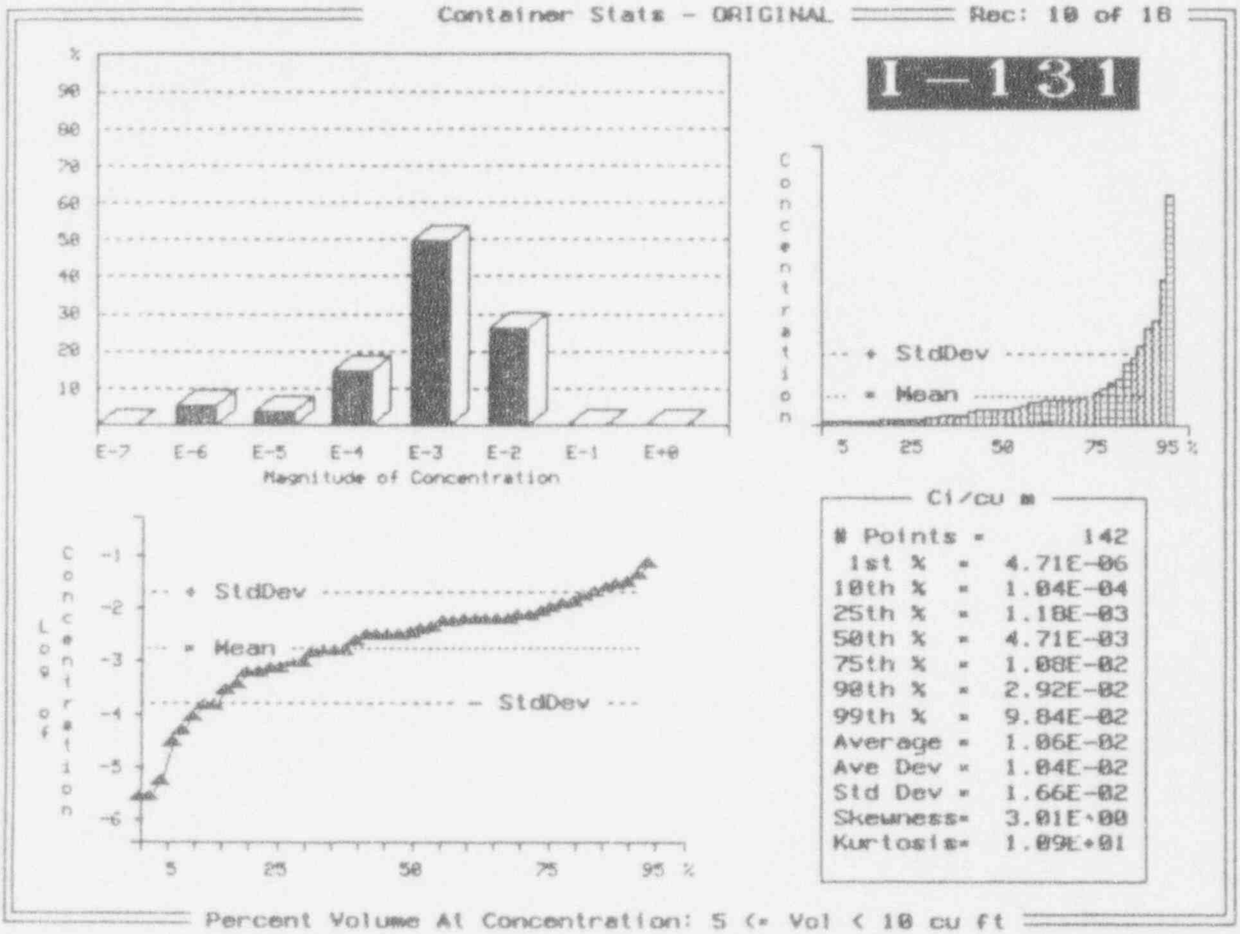

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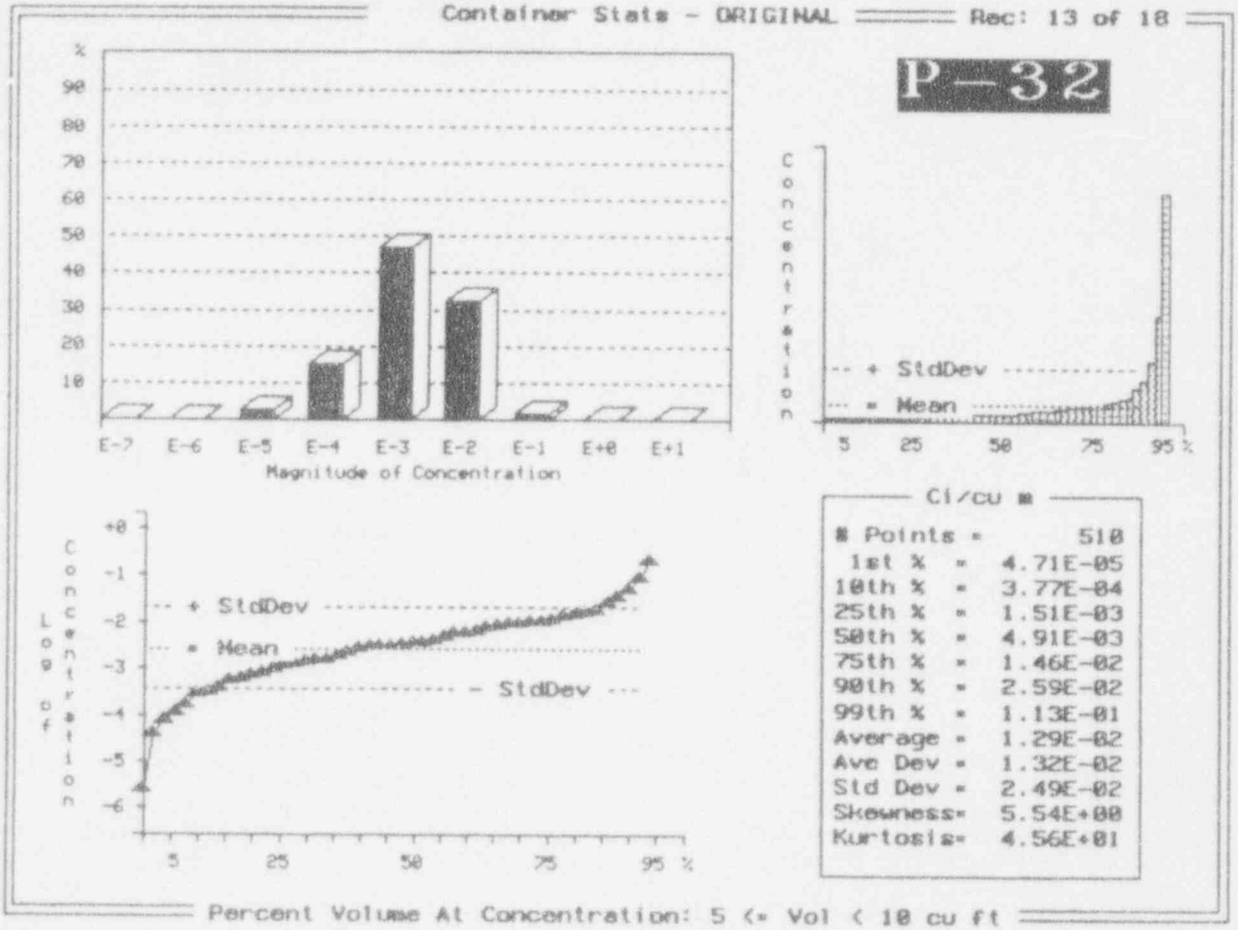
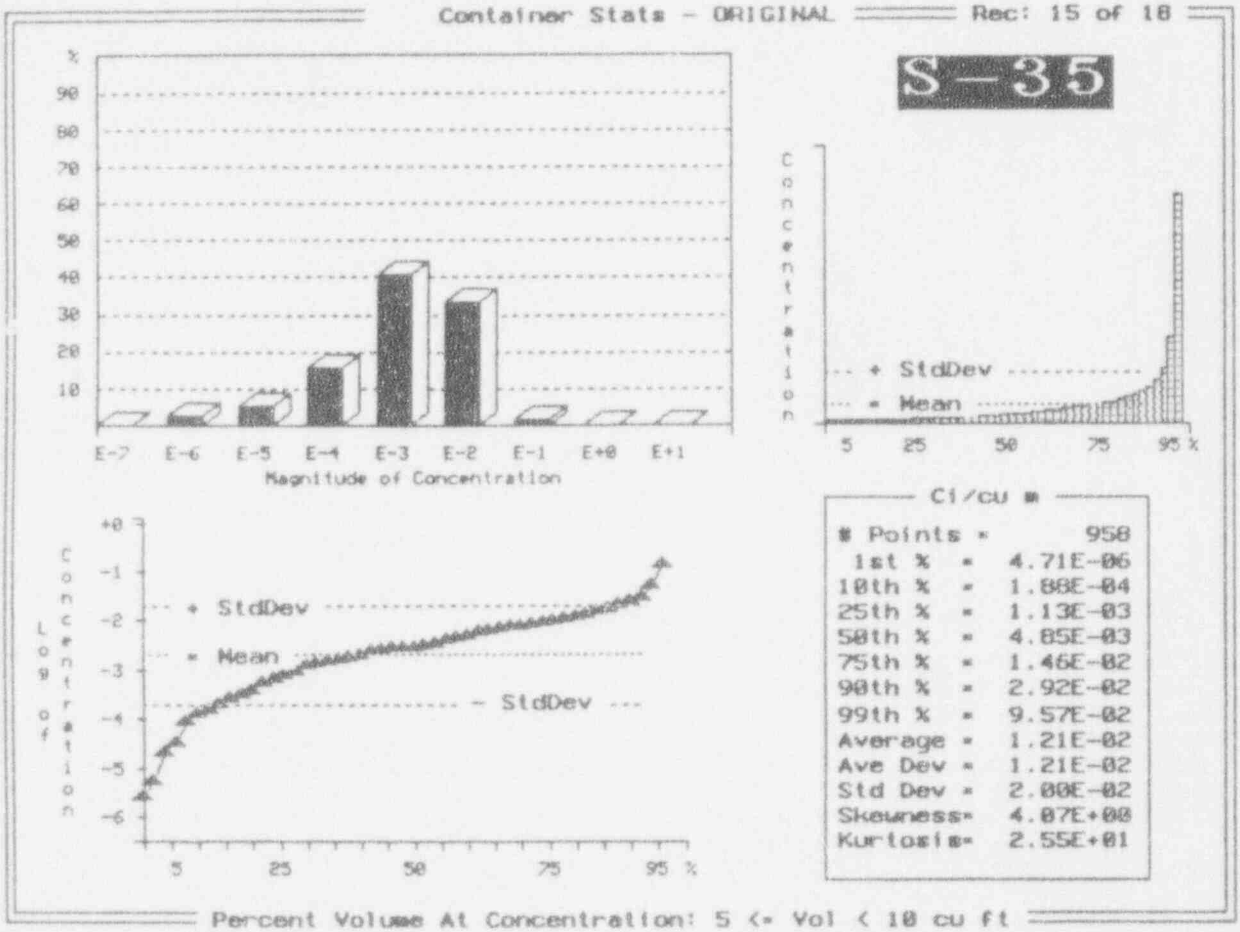


Exhibit 3-1 (Continued)



As indicated in Exhibit 3-1, the sort captured 51 radionuclides. However the radionuclides listed above account for 22.7 of the 23.3 Curies (or 97%) captured by the sort.

The results indicate that average radionuclide concentrations for the principal radionuclides are on the order of 10^{-2} to 10^{-3} Ci/m^3. 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, which corresponds to a 55-gallon drum concentration of 4.7E-06 Ci/m^3. The 99th percentile values appear to be about a factor of five higher than the 90th percentile values.

Appendices C and D present all the non-brokered, Class A, container-level data sorted according to Compact or unaffiliated State and waste streams and should be consulted for more detailed information on academic waste. Using the data obtained from Appendix C, Table 3-4 compares selected radionuclide concentration distributions for specific waste streams and for different regions of the United States. These radionuclides comprise over 90 percent of the activity shipped for disposal by academic waste generators. The results indicate that at all percentile values, the concentrations of the selected radionuclides among the different waste forms are within one to two orders of magnitude of each other.

The detailed results presented in Appendix C indicate that the major radionuclides include H-3, C-14, Na-22, P-32, P-33, S-35, Cl-36, Ca-45, Sc-46, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ge-68, Ga-68, Se-75, Rb-86, Sr-85, Sr-90, Tc-99, Ru-103, Ru-106, Cd-109, Ag-110m, In-111, In-114m, Sn-113, I-125, I-131, Ba-133, Cs-134, Cs-137, I-125, Ce-141, Gd-153, Ra-226, Am-241, and U-238.

The radionuclides listed above make up over 99 percent of the activity shipped to the disposal sites. Radionuclides that are infrequently reported or that make up relatively lower waste activity levels are not included in Appendix C. These include isotopes of uranium and plutonium, natural uranium and thorium, depleted uranium, antimony, europium, platinum, bismuth, lead, and transuranics (TRU).

Table 3-4

Comparison of Selected Radionuclide Concentration Distributions in Container-Level Academic Waste

	Radionuclide (pCi/g) - Percentile											
	C-14			H-3			Cr-51			I-131		
	1	50	99	1	50	99	1	50	99	1	50	99
<u>Aggregate</u>	4.7E-6	4.0E-4	2.1E-2	4.2E-5	6.1E-3	3.1E-1	4.7E-6	1.9E-3	8.8E-2	4.7E-6	4.7E-3	9.8E-2
<u>Northwest</u>												
Absorbed Aqueous Liquids	5.3E-5	7.5E-3	5.2E-1	7.5E-5	5.4E-2	4.1E+0	1.0E-2	2.3E-1	5.3E-1	1.9E-2	5.3E-2	3.8E-1
Animal Carcasses	4.7E-6	1.4E-4	9.4E-2	4.7E-6	1.2E-1	3.1E-1	4.7E-6	1.4E-4	4.7E-4	4.7E-6	2.4E-4	9.4E-3
Dry Solid	4.7E-6	1.4E-3	3.4E-2	3.8E-5	1.3E-2	2.7E-1	4.7E-6	1.7E-2	1.3E-1	4.7E-6	7.1E-3	9.8E-2
Compacted DAW	4.7E-6	9.4E-4	2.1E-2	4.7E-6	1.6E-2	6.9E-1	4.7E-6	1.2E-2	9.4E-2	2.4E-4	3.8E-3	3.4E-2
<u>Rocky Mountain</u>												
Absorbed Aqueous Liquids	9.4E-6	4.7E-4	4.3E-3	3.7E-2	5.5E-2	8.5E-2						
Animal Carcasses	9.4E-6	1.1E-3	2.9E-3	3.8E-5	9.2E-3	5.5E-2	4.7E-6	6.1E-5	1.9E-4			
Compacted DAW	4.7E-6	4.7E-5	2.6E-3	1.4E-5	1.9E-3	2.1E-1						
<u>Southwest</u>												
Dry Solid	2.3E-4	3.8E-4	9.9E-4	9.9E-4	9.4E-3	1.0E-2						

Overall, the data reveal that radionuclide concentrations among containers vary over six orders of magnitude. Mass concentrations range from 4.0 pCi/g to 6.0 x 10^6 pCi/g. In addition, the various waste streams include dry solids, sorbed aqueous liquids, animal carcasses, compacted dry active waste, solidified liquids, biological waste, non-compacted dry active waste, aqueous liquids in vials and sorbents, activated metals and concrete, and spent resins.

Appendix D presents information similar to that provided in Appendix C, except that it is sorted by waste form or stream only (i.e., the data are not sorted by Compact). For this sector, Appendix D presents radionuclide concentration distributions for compacted dry solids, sorbed aqueous liquid, and solidified liquids.

A review of Appendix D reveals a similar radionuclide distribution, including C-14, H-3, Na-22, P-32, S-35, Cl-36, Ca-45, Sc-46, Cr-51, Co-57, Fe-59, Co-60, Zn-65, Ge-68, Se-75, Sr-85, Nb-95, Tc-99, In-111, I-125, I-131, Ce-141, Gd-153, and Ra-226. Radionuclide concentrations vary over six orders of magnitude, typically from about 3 to 7.0 x 10^6 pCi/g, e.g., for H-3, P-32, S-35, and I-125. The results represent varied waste volumes and activity levels depending upon waste forms or streams. For example, the sort for dry solid waste captured 11 shipments containing 324 containers, while the sort for absorbed aqueous liquid waste captured 9 shipments containing 1,154 containers.

3.3.2 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 by academic generators from 1986 to 1990:

- 438 shipping manifests
- 2,037 cubic meters of waste
- 1.16E+06 kg of waste, 0.57 g/cm^3 average density
- 170 Ci of total activity, 0.08 Ci/m^3

Upon inspection, Table 3-2 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered, by academic waste generators from 1986 to 1990 was 7,272 cubic meters and 5,306 Ci, respectively. Accordingly, this search represents about 28 percent of the volume (the other 72 percent was shipped by brokers and a very small portion is Class B and C waste) and 3.2 percent of the activity of the waste shipped for disposal by academic waste generators. Class B and C waste typically contain the majority of the radioactivity shipped for disposal. In addition, the average gross radionuclide concentration in the sort is about 0.08 Ci/m^3, while the average gross radionuclide concentration in all academic waste is about 0.73 Ci/m^3. These radionuclide concentration results are consistent with the results of the container level analysis.

As noted earlier, data at the shipment level do not provide the means to sort by waste stream. These data characterize aggregate radionuclide concentrations over the entire waste volume and mass of the shipment. The analyses represent aggregate practices based on direct shipments to all disposal sites and for all years (1/1/86 to 11/30/90).

Exhibit 3-2 presents concentration distributions of the principal radionuclides contained in shipments. The sorts are grouped into the following categories of shipment sizes:

- <10 cubic feet per shipment
- 10 to 50 cubic feet per shipment
- 50 to 100 cubic feet per shipment
- 100 to 500 cubic feet per shipment
- 500 to 1,000 cubic feet per shipment

The results of the search revealed that the majority of the waste volume and activity are contained in the 100 to 500-cubic foot shipment size category. The concentration distributions for the principal radionuclides are summarized below:

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	3.3E+00	4.5E-04	1.2E-03	1.4E-05	3.4E-05	3.7E-03	9.5E-03
Ca-45	700	7.5E-01	1.6E-04	5.2E-04	5.6E-07	8.3E-06	1.1E-03	1.0E-02
Cr-51	700	5.2E+00	1.0E-03	2.6E-03	2.1E-07	3.6E-05	9.0E-03	1.4E-02
H-3	40	8.8E+01	6.8E-03	2.5E-02	6.8E-05	6.8E-04	5.1E-02	2.5E-01
I-125	700	2.4E+01	5.7E-03	8.2E-03	3.8E-05	5.3E-04	1.7E-02	3.5E-02
P-32	700	2.3E+01	7.9E-03	1.2E-02	2.1E-06	5.6E-04	3.0E-02	6.5E-02
S-35	700	1.5E+01	3.3E-03	7.1E-03	5.6E-06	1.1E-04	1.8E-02	4.2E-02
	Total	1.59E+02						

Though the sort captured 121 radionuclides, the seven listed here constitute 159 of the 170 Curies (93%) captured by the sort.

The shipment-level data were also sorted by Compact and State to determine the degree to which radionuclide concentration distributions vary regionally. The results of these sorts are shown in Appendix E. Table 3-5 summarizes these results for the key radionuclides. The results reveal that at the 50th percentile level, the aggregate radionuclide concentrations at the container and shipment level agree within a factor of two. This implies that the container-level data, although consisting principally of data from the Northwest and Rocky Mountain Compacts, appear to be representative of all academic waste shipments.

EXHIBIT 3-2

ACADEMIC WASTE - SHIPMENT LEVEL ANALYSIS

Number of shipping records captured:	438
Number records with container data:	19*
Number of manifests captured:	0
Number of container records captured:	2,452
Number of isotope records captured:	3,926
Total activity of shipment (Ci):	1.70E+02
Total volume of shipments (m^3):	2.04E+03
Computed weight of shipments (kg):	1.16E+06
Total weight of containers (kg):	1.56E+05*
Nominal density (g/cm^3):	5.68E-01
Total density (g/cm^3):	5.25E-01*
Total concentration (Ci/m^3):	8.35E-02
Total concentration (pCi/g):	1.50E+05*

* For shipments with container data.

Exhibit 3-2 (Continued)

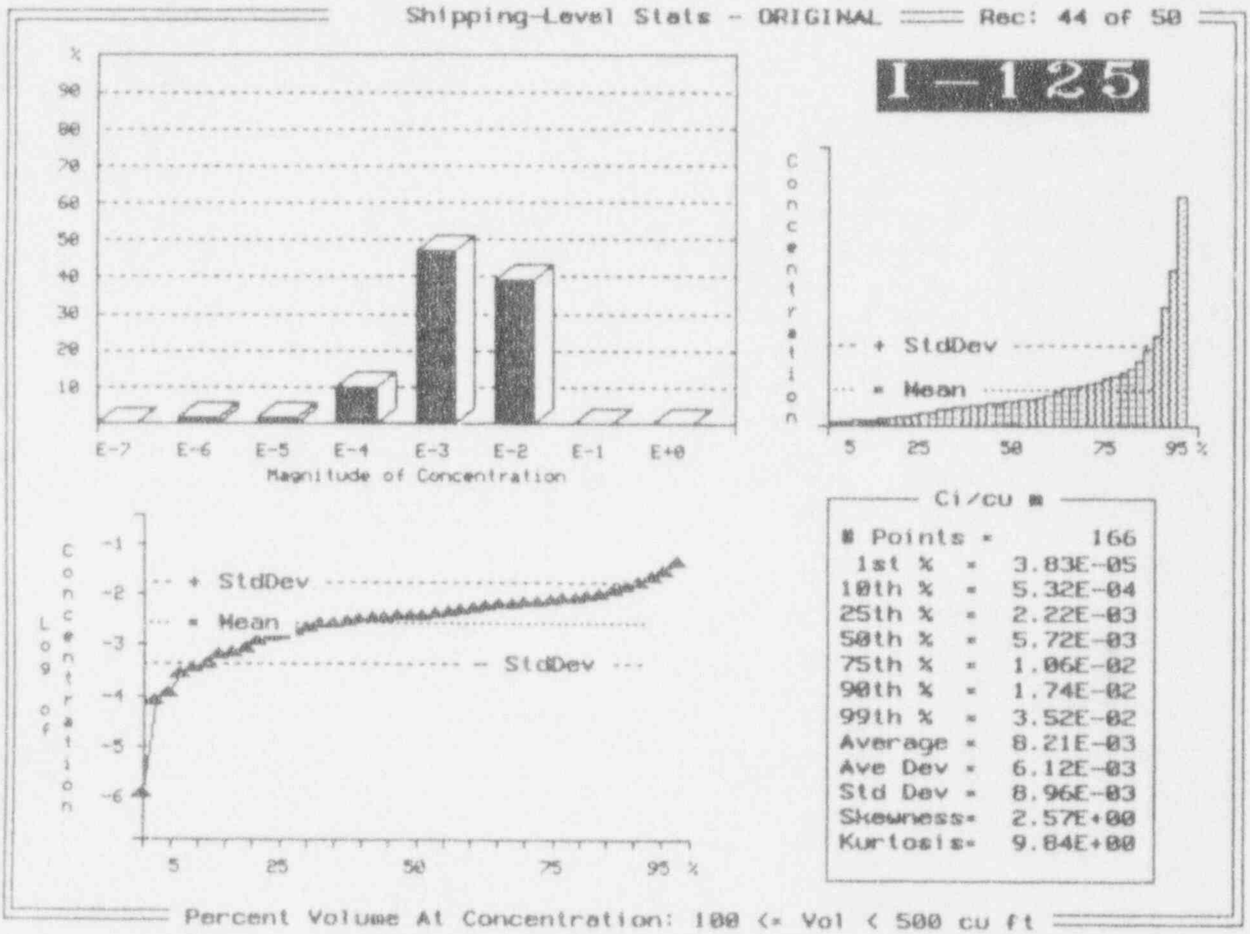


Exhibit 3-2 (Continued)

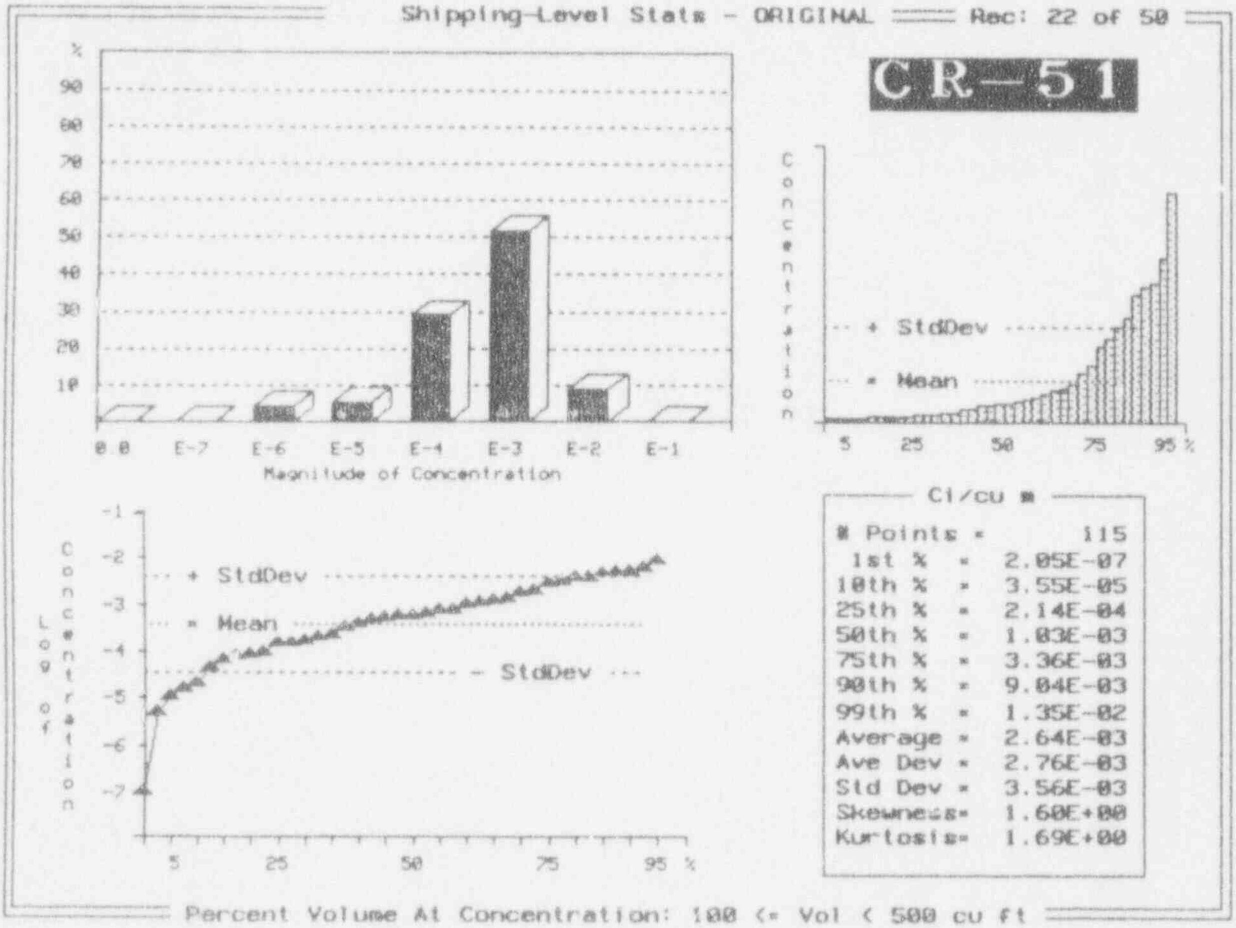
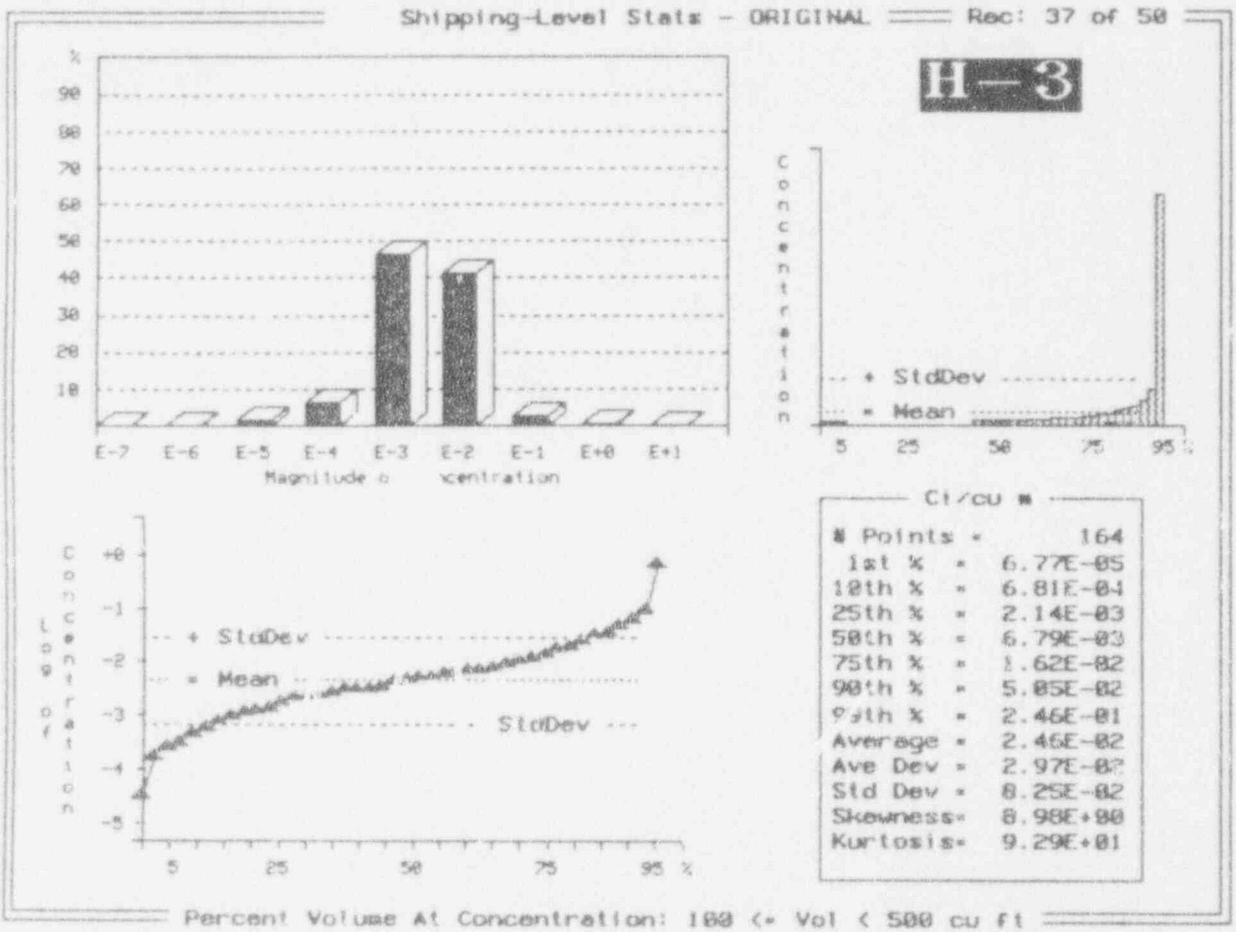


Exhibit 3-2 (Continued)



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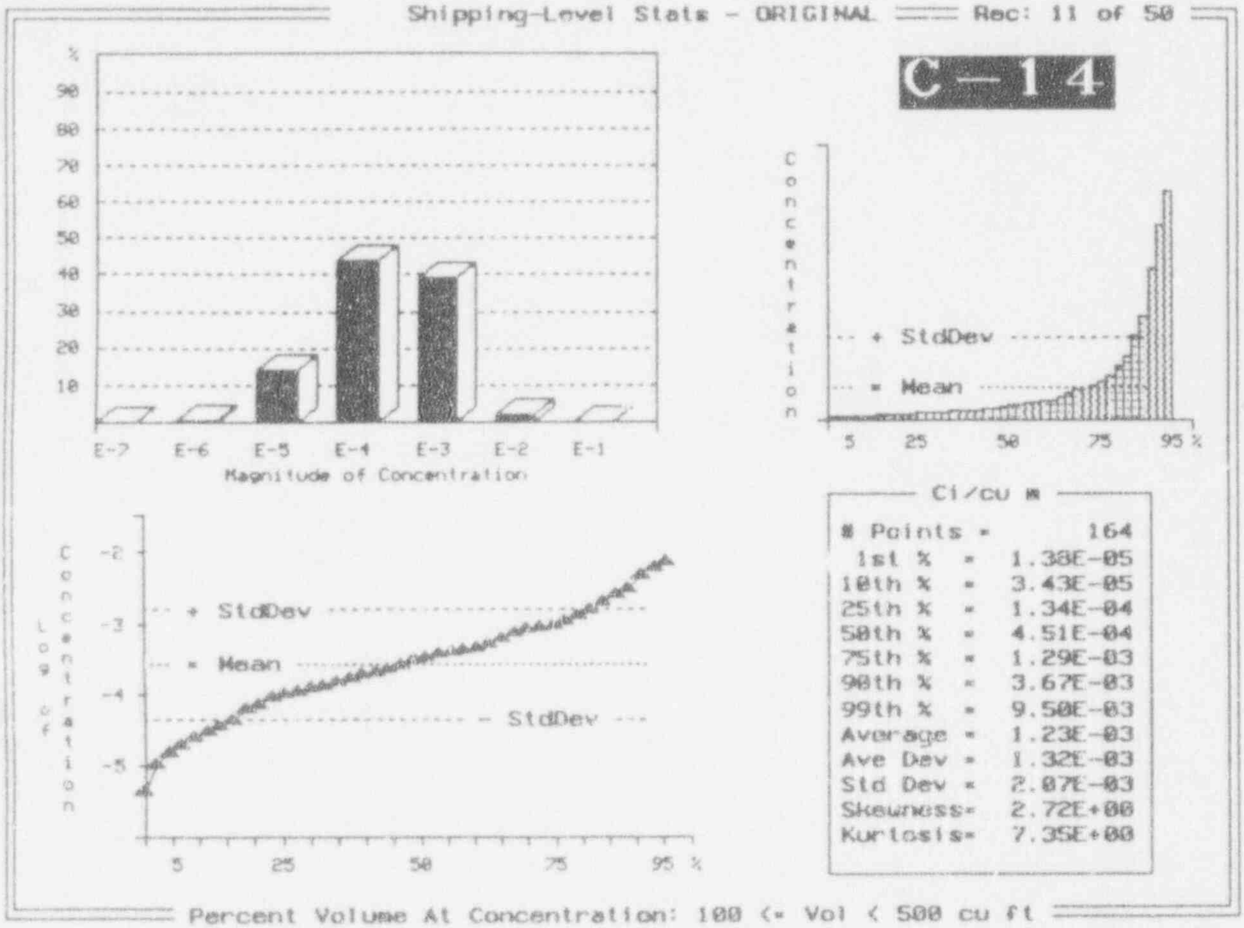

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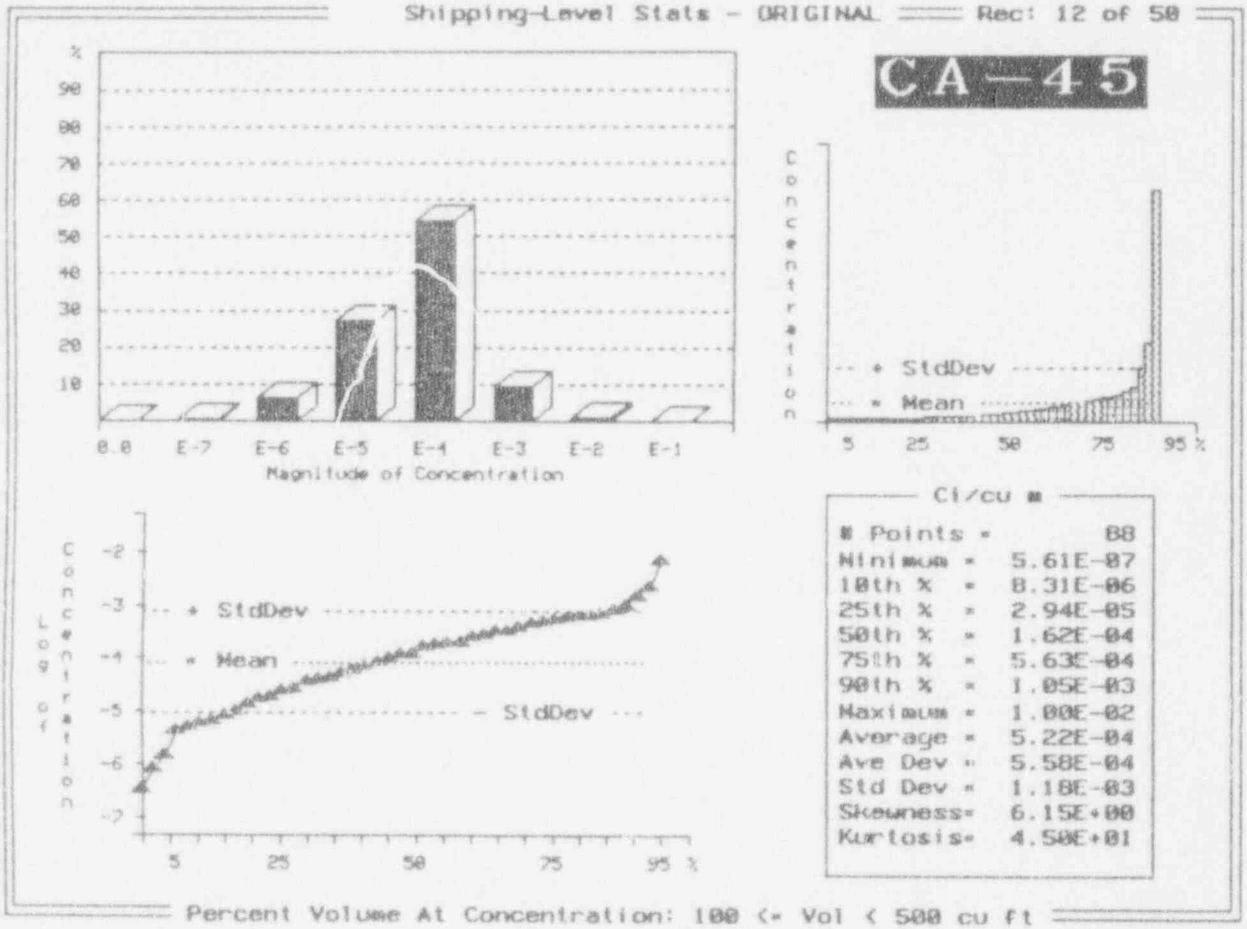

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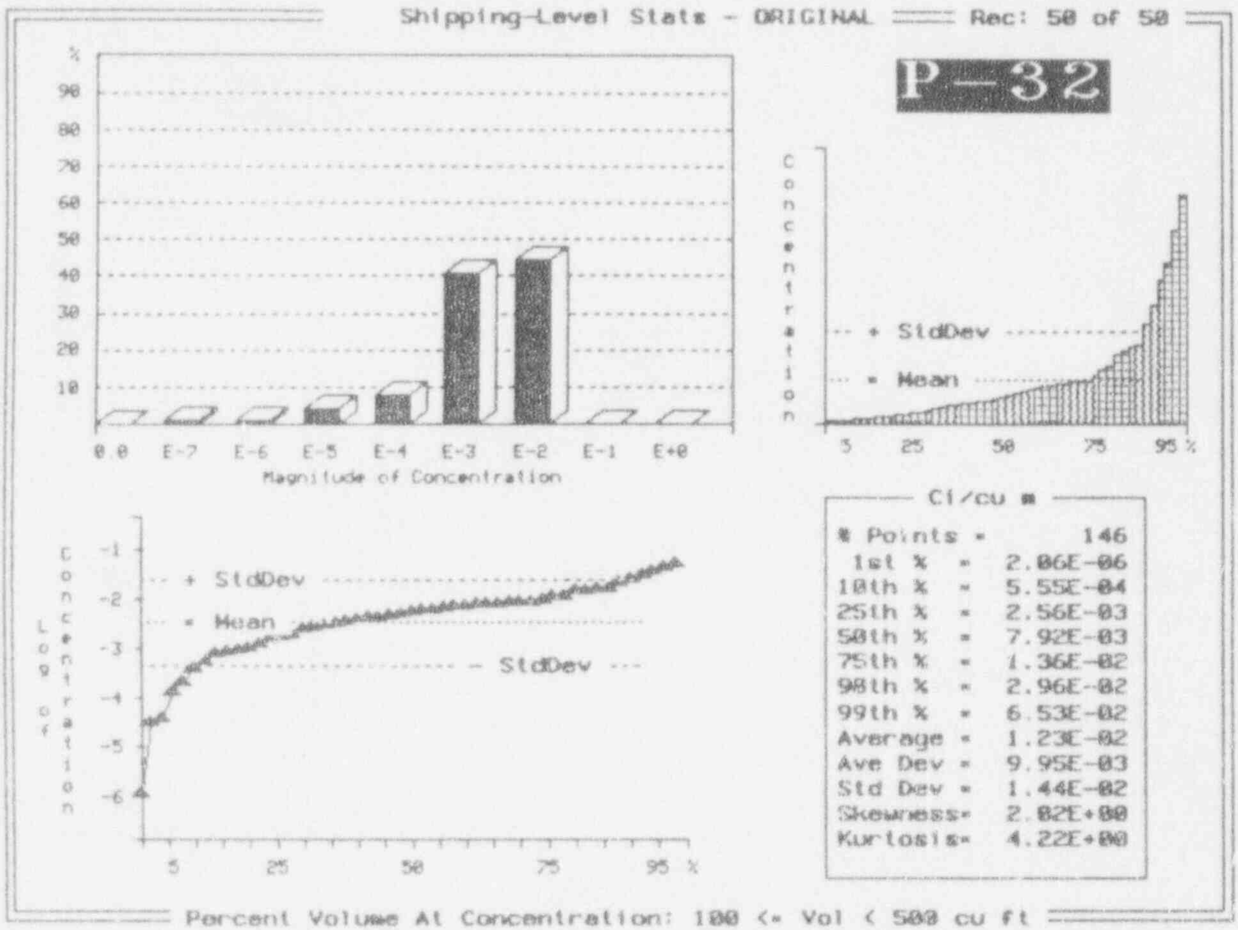

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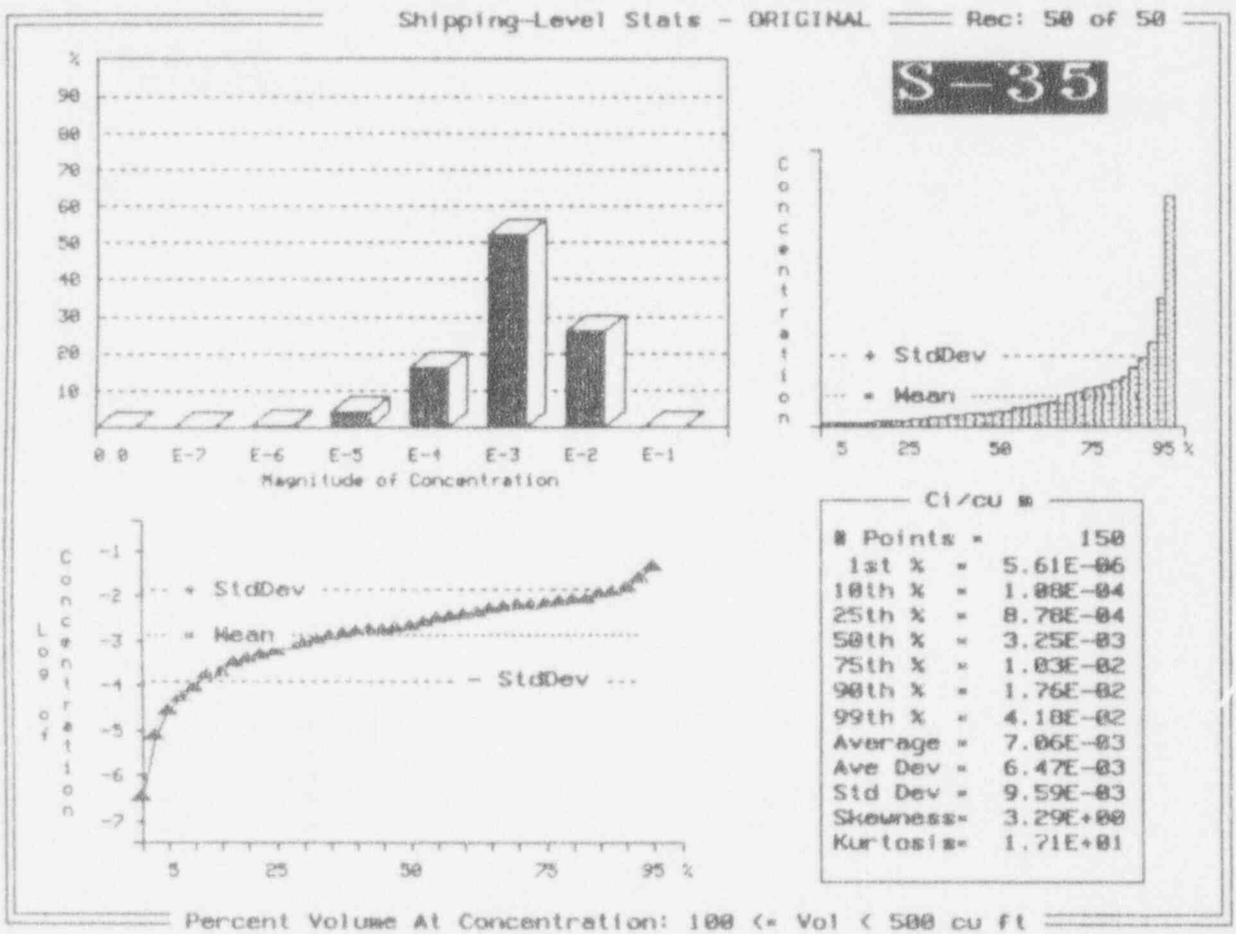


Table 3-5

Comparison of Selected Radionuclide Concentration Distributions at the Shipment Level for Academic Waste Generators (1986 to 1990)

	Total Volume (m^3)	Volume Captured (m^3)	Radionuclide (Ci/m^3) - Percentile C-14 1	C-14 50	C-14 99	H-3 1	H-3 50	H-3 99	Cr-51 1	Cr-51 50	Cr-51 99	I-131 1	I-131 50	I-131 99
Aggregate Container Level			4.7E-6	4.0E-4	2.1E-2	4.2E-5	6.1E-3	3.1E-1	4.7E-6	1.9E-3	8.8E-2	4.7E-6	4.7E-3	9.8E-2
Aggregate Shipment Level			1.4E-5	4.5E-4	9.5E-3	6.8E-5	6.8E-3	2.5E-1	2.1E-7	1.0E-3	1.4E-2			
Shipment Level By Compact														
Northwest	333	256	5.6E-4	2.9E-3	1.0E-2	3.9E-4	7.1E-2	3.5E-1	1.3E-3	1.1E-2	1.5E-2	2.5E-7	1.8E-3	8.5E-3
Rocky Mountain	278	64	1.2E-4	2.5E-4	3.7E-4	1.5E-2	1.8E-2	3.9E-2	3.2E-6	4.1E-6	1.4E-4	9.6E-7	9.6E-7	9.6E-7
Central	33	2	Only 1 shipping record											
Midwest	927	39	5.3E-5	1.2E-4	1.6E-3	6.8E-6	1.8E-3	9.1E-3	7.0E-4	9.7E-4	2.6E-3			
Central Midwest	242	21	5.5E-6	6.3E-3	7.4E-3	1.2E-2	1.2E-2	1.5E-2						
Southeast	1,210	908	6.7E-6	2.9E-4	2.6E-2	6.8E-5	5.1E-3	2.5E-1	9.7E-6	1.3E-3	1.2E-2	6.1E-6	8.7E-4	8.0E-3
Northeast	890	518	1.1E-6	4.8E-5	7.8E-3	1.1E-6	1.9E-3	1.4E-1	5.1E-6	3.0E-4	4.0E-3	5.2E-7	2.0E-3	2.6E-2
Appalachian	382	56	2.4E-5	3.3E-3	1.2E-2	6.9E-4	4.0E-3	6.3E-2	5.2E-4	3.5E-3	5.6E-3	8.9E-8	8.9E-8	2.8E-4
Southwest	1,960	497	1.4E-5	7.2E-4	1.1E-2	5.4E-5	9.3E-3	9.4E-1	2.9E-6	3.2E-4	1.6E-2	1.8E-6	2.4E-4	8.0E-4
DC	14	2	Only 1 shipping record											
Maine	4	4	Only 1 shipping record											
Massachusetts	113	29	1.3E-5	2.7E-4	2.6E-2	4.1E-5	1.2E-2	5.4						
New Hampshire	4	1	Only 1 shipping record											
Rhode Island	28	9	1.8E-5	9.0E-5	6.9E-1	1.6E-4	1.0E-3	1.3E-2						
Texas	410	0												
Vermont	34	18	1.3E-4	4.3E-4	7.0E-4	3.0E-3	3.4E-2	1.0E-1	9.2E-5	7.6E-4	1.7E-3			
New York	410	59	3.8E-6	2.0E-3	1.6E-1	2.4E-5	8.9E-3	7.8E+0	8.5E-4	2.4E-3	1.6E-2	8.8E-4	8.8E-4	2.6E-3

The results also indicate that the variability of radionuclide concentrations within a region and given radionuclide is large as compared to the variability among regions. Accordingly, it appears that radionuclide concentrations among regions do not differ significantly.

These results are also complemented with histograms and cumulative distribution curves shown in Appendix F. Radionuclide histograms and cumulative distributions are presented only for those radionuclides that are consistently being reported by waste generators. The results also include summary sheets providing additional information for each Compact and State, including the associated number of waste generators, total number of shipping records and containers (as is applicable), shipment weights, and total and fractional waste volumes and activity levels.

A review of the data shown in Appendix E reveals that the most often cited radionuclides include C-14, H-3, Na-22, Na-24, P-32, S-35, Cl-36, Ca-45, Sc-46, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ga-68, Ge-68, Kr-85, Rb-86, Sr-85, Sr-89, Y-88, Y-90, Sr-90, Nb-95, Tc-99, Tc-99m, Ru-103, Ru-106, Cd-109, Ag-110m, In-111, In-114m, Sn-113, I-121, I-125, I-131, Ba-133, Xe-133, Cs-134, Cs-137, Cs-134, I-131, Ce-141, Pm-147, Gd-153, Yb-169, Au-198, Tl-201, Tl-204, Hg-203, Po-210, Ra-226, Th-232, U-238, and Am-241.

Radionuclide concentrations were observed to vary over 8 orders of magnitude, from 0.01 to 10^6 pCi/g. Most radionuclides, however, fall within a narrower range of 10^1 to 10^4 pCi/g. For a few radionuclides (e.g., H-3, C-14, P-32, S-35, and I-125), concentrations were observed to be noticeably higher, from 10^5 to 10^6 pCi/g. The results represent varied waste volumes and activity levels depending upon waste forms or streams and individual waste generators. For example, the results characterize waste associated with single to multiple number of shipments (up to 135) and from 167 to 1,679 waste containers. They comprise from 0.6 to 97 percent of the waste volumes and 0.01 to 93 percent of the total activity.

Even though some analyses captured 97 percent of the waste volumes, such results are not significant since the associated waste volumes and activity levels are usually minimal. For example, capturing 80 percent of the waste volume for Vermont is not as significant as capturing only 10 percent that of the Southeast Compact. Omitting these extremes, the analyses captured 4.2 to 77 percent of the waste volume, averaging about 34 percent, across all Compacts and States. Similar results are noted for activity distributions, typically ranging from 1.2 to 77 percent, averaging at about 30 percent. These results, however, are anticipated as the analyses targeted only Class A waste, while it is known that most of the activity is contained in Class B and C waste.

3.4 Mixed Waste

Mixed waste, characterized by both hazardous chemical and radioactive properties, are generated during various activities when chemicals are introduced as cleaning agents or solvents. Activities that may result in the generation of mixed waste include R&D, laboratory analyses, and decontamination activities. Furthermore, actual generation rates are highly variable and are dependent upon specific facility practices.

Mixed waste generation rate estimates are based on the results of the National Profile on Commercially-Generated Low-Level Radioactive Mixed Waste (NUREG/CR-5938), as such waste is not being shipped to the disposal sites (NRC92). Consequently, the low-level waste database does not contain such information. The generation rates were weighted on a national basis to account for facilities which did not respond to the survey and those that were not queried during the survey.

Table 3-6 summarizes the results of the 1990 National Profile for academic waste generators. The results indicate that spent scintillation fluids make up about 93 percent of the waste volume.

Table 3-7 summarizes the results by Compact regions and States. The results indicate that six Compacts and two States generate about 93 percent of the estimated waste volume. In decreasing order, they are the Midwest, Southeast, Southwest, and Appalachian Compacts, the State of Massachusetts, the Central Midwest Compact, New York State, and the Northwest Compact. The total 1990 mixed waste volume for all regions has been estimated to be 28,982 ft^3.

3.5 Academic Waste Generators - Class A Waste Description and Characteristics of Typical Academic Waste Generators

The purpose of this section is to identify waste streams or forms, volumes, and radionuclide distributions that best characterize typical facilities in the academic sector. This section emphasizes the volume and activity of waste per waste generator, as opposed to the previous sections, which emphasized the academic category as a whole.

Table 3-6 Academic Institutions Mixed Waste Profile - 1990[a]

Waste Stream	Weighted Annual Generation Rate (ft³/yr)	Percent
Liquid Scintillation Fluids	26,919	92.9
Waste Oils	15	0.05
Chlorinated Organics	512	1.8
Chlorinated Fluorocarbons	(b)	--
Other Organics	251	0.9
Metals (Pb, Cr)	49	0.2
Corrosive Materials	71	0.2
Other Materials	1,165	4.0
Total	28,982	(b)

(a) Data extracted from NUREG/CR-5938, Table 4-6 (NRC92).
(b) Result may not add up to 100% due to rounding off.

3.5.1 Waste Streams and Forms

The following Class A waste streams are representative of 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, and
- solidified and absorbed aqueous liquids.

These waste streams are routinely produced by the majority of generators, make up a large fraction of the total waste volume, and can be relatively well characterized by their radiological and physical properties. Other waste streams include activated metals and concrete from research reactors and accelerators, unspecified forms of biological waste, and aqueous liquids. These wastes are typically generated in low volumes, may be characterized by unusual physical or chemical properties, and may contain long-lived radionuclides at higher concentrations.

Table 3-7 Academic Institutions - 1990 Regional Mixed Waste Generation Profile[a]

Compact/State	Estimated Volume (ft^3)
Northwest	1,160
Rocky Mountain	201
Central States	493
Midwest	9,084
Central Midwest	2,071
Southeast	4,448
Northeast	395
Appalachian	2,664
Southwest	3,729
Maine	15
Massachusetts	2,434
New York	1,419
Texas	380
Vermont	297
New Hampshire	(b)
Rhode Island	(b)
District of Columbia	192
Puerto Rico	(b)
Total	28,982

(a) Data extracted from NUREG/CR-5938, Table 4-10 (NRC92).
(b) No data reported or facilities were not surveyed.

3.5.2 Waste Volume

Tables 3-8 and 3-9 present averages, ranges, waste volumes, and total number of waste generator identification codes by Compact regions or States. The data characterize overall practices from 1986 to 1990. For example, the average academic waste generator located in the Rocky Mountain Compact produced 21.4 m^3 of waste from 1986 to 1990. The yearly average generation rate is derived by dividing the tabulated waste volume by five, in this example, about 4.3 m^3.

Table 3-9 shows that the waste volume shipped in the Rocky Mountain Compact varies over four orders of magnitude, from 0.00283 to 105 m^3 per waste generator from 1986 to 1990. At the 50th percentile, the aggregate waste volume is 0.0566 m^3, yielding a yearly average of 0.011m^3 per generator. Similar case comparisons can be made for other Compact regions or States. For more details on waste volume distributions, refer to Appendix F.

A point of clarification is in order for the data characterizing the number of waste generators. The number of waste generators identified here (and in the summary sheets of Appendix F) is based on unique waste generator identification codes assigned by the disposal sites. The number of generators represents all the waste generators that ever shipped waste from 1986 to late 1990, but does not necessarily reflect the current population size. It is not uncommon for some waste generators to have access to two disposal sites. In such instances, a single generator would have two identification codes. It is not possible, however, to identify such waste generators nor to assess the extent of such practices. Finally, it is not possible to determine if the distribution of waste generators has changed over the reported period.

3.5.3 Radionuclide Distributions and Concentrations

Waste activity distributions by Compact regions and States are shown in Table 3-10. As can be noted, waste activity levels vary significantly among regions. The total activity shipped by waste generator, over the time period from 1986 to 1990, varies over eight orders of magnitude. At the 50th percentile, aggregate waste activities are relatively more stable, spanning four orders of magnitude across all Compact or States. For more details on waste activity distributions, see Appendix F figures and tabulations.

Table 3-8 Waste Volume Distribution Among Academic Generators by Compact Regions and States[a]

Compact/State	No. of Unique Gen. Code	-- Waste Volume - m^3[b] Five-Year Total Vol. All Gen.	Ave. Gen. Five-Year Total Vol.	-- Ave. Gen. Yearly Volume
Northwest	21	333	15.9	3.2
Rocky Mountain	13	277	21.4	4.3
Central	14	33	2.4	0.5
Midwest	65	927	14.3	2.9
Central Midwest	28	242	8.6	1.7
Southeast	71	1,211	17.1	3.4
Northeast	24	890	37.1	7.4
Appalachian	46	382	8.3	1.7
Southwest	74	1,957	26.4	5.3
District of Columbia	7	14	2.0	0.4
Maine	2	3.7	1.8	0.4
Massachusetts	18	113	6.3	1.3
New Hampshire	1	3.5	3.5	0.7
New York	84	409	4.9	1.0
Puerto Rico[c]	---	---	---	---
Rhode Island	5	28	5.6	1.1
Texas	27	410	15.2	3.0
Vermont	3	3.4	1.1	0.2
Total:	503	7,237	192	39
- Low:	1	3.4	1.1	0.2
- High:	84	1,957	37.1	7.4
- Average:	30	426	11.3	2.3
- Std. Dev.:	28	537	10.0	2.0

(a) Compiled from data given in Appendix F for all Class A waste forms.
(b) Aggregate and yearly average waste generation rates are rounded off. See text for details. To convert volume to to cubic feet, multiply cubic meter by 35.3.
(c) No waste disposed of during the reported period.

Table 3-9 Academic Waste Volume Distributions Among Compact Regions and States[a]

Compact/State	Waste Volume (m^3) per Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	1.53E-02	1.21E+00	1.94E+02
Rocky Mountain	2.83E-03	5.66E-02	1.05E+02
Central	3.11E-02	1.24E+00	7.97E+00
Midwest	2.83E-03	1.28E+00	3.00E+02
Central Midwest	2.55E-03	4.75E-01	8.83E+01
Southeast	1.98E-03	2.31E+00	2.86E+02
Northeast	1.90E-02	3.01E-01	2.78E+02
Appalachian	2.83E-03	2.12E-01	1.42E+02
Southwest	1.13E-02	4.59E-01	6.10E+02
District of Columbia	1.42E-02	6.21E-01	5.67E+00
Maine	6.88E-02	6.88E-02	3.61E+00
Massachusetts	4.25E-02	2.12E+00	3.53E+01
New Hampshire	3.50E+00	3.50E+00	3.50E+00
New York	1.33E-02	2.12E-01	6.73E+01
Puerto Rico[c]	---	---	---
Rhode Island	1.16E-02	6.49E+00	9.91E+00
Texas	1.76E-02	6.98E+00	1.16E+02
Vermont	6.80E-02	1.57E-01	1.81E+01

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or generators no longer producing waste. See text for details.
(b) Yearly waste generation distributions may be approximated by dividing above values by five. To convert volume to cubic feet, multiply cubic meter by 35.3
(c) No waste disposed of during the reported period.

Table 3-10 Academic Waste Activity Distributions Among Compact Regions and States[a]

Compact/State	Waste Activity (Ci) per Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	3.00E-06	6.04E-02	2.75E+01
Rocky Mountain	2.20E-05	1.22E-02	8.37E+00
Central	1.00E-06	1.20E-02	2.64E+00
Midwest	2.00E-04	5.06E-02	6.86E+01
Central Midwest	9.23E-04	9.53E-03	3.27E+00
Southeast	1.00E-04	1.34E-01	4.62E+02
Northeast	7.00E-06	2.20E-03	1.90E+01
Appalachian	9.00E-06	4.10E-03	1.41E+01
Southwest	5.00E-06	5.50E-03	4.27E+01
District of Columbia	5.40E-05	2.94E-02	1.03E+00
Maine	1.13E-02	1.13E-02	9.29E-02
Massachusetts	1.30E-05	4.05E-02	4.99E+01
New Hampshire	5.71E+01	5.71E+01	5.71E+01
New York	4.00E-05	9.08E-03	1.72E+01
Puerto Rico[c]	---	---	---
Rhode Island	8.00E-04	1.30E-02	7.68E-01
Texas	2.00E-05	7.82E-02	5.45E+01
Vermont	8.00E-05	4.73E-01	5.16E-01

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or generators no longer producing waste. See text for details.
(b) Yearly waste activity distributions may be approximated by dividing above values by five. An entry shown as 0.00E-00 indicates that the database did not have a value for that record. 1 Ci = 3.7 x 10^{10} Bq.
(c) No waste was disposed of during the reported period.

The most often cited radionuclides include C-14, H-3, Na-22, P-32, S-35, Ca-45, Sc-46, Cr-51, Mn-54, Co-57, Co-60, Ni-63, Zn-65, Se-75, Sr-85, Nb-95, Tc-99, Tc-99m, Ru-103, In-111, In-111, I-125, I-131, Ce-141, and Ir-192. This list is not all-inclusive since, as addressed earlier, other radionuclides are present at times. This approach is used here to focus only on practices that can be reliably characterized. Practices that occur only infrequently involve rare waste forms and are characterized by relatively few or exotic radionuclides, which make it difficult to assess waste generation and disposal practices.

3.6 Geographic Distribution and Demographics of Academic Waste Generators

3.6.1 Geographical Distribution

Academic waste generators are located in both urban and rural areas. Most of the major academic waste generators, however, are located in large metropolitan centers. Such generators are also associated with large research centers. There are no specific reasons for the location of such facilities, other than meeting regional educational needs. In many instances, the establishment of such academic facilities pre-dates the use of radioactive materials as a research tool. Some facilities have had to build new research centers to address new research objectives. Typically, new laboratories have been built near existing facilities, often located in the same or nearby communities.

The locations of the major academic waste generators are identified by city, county, and state (see Appendix G-1). Academic waste generators may have more than one location identified under the same NRC and Agreement State license. However, it does not follow that all identified locations necessarily generate any waste.

The information contained in Appendix G-1 was extracted from periodic reports issued by Compacts and States. Some states, however, did not provide this information since some generators and states have deemed this type of data to be confidential.

3.6.2 Demographics

Population data were obtained from the Bureau of Census based on the 1990 census results (DOC92). The data were sorted to tally population counts by Compact, State, and county, when identified. Population data were compiled for each of the nine Compacts and nine unaffiliated States (see Appendix G-2).

4.0 GOVERNMENT INSTITUTIONS

4.1 Introduction

Government institutions include research and testing environmental laboratories, medical facilities, military installations, and other types of facilities, such as depots, research stations, airports, shipping ports, etc. Government facilities are run by federal, state, or local agencies, or by private organizations under government contracts.

Government institutions are involved in diverse types of activities, such as industrial research, materials testing, organic and inorganic chemistry, geological and mineral exploration, and basic and applied research in various scientific or technical disciplines. They include aeronautical research, naval and maritime operations, production of conventional weapons, surface and air transportation, consumer product testing, agriculture, food and drug testing, and environmental monitoring and surveillance, for example.

Radioactive materials used in these activities are produced by research reactors and particle accelerators and are also supplied by radio-chemical laboratories. Radioactive materials may be obtained commercially or produced on site. Waste generated by Department of Energy facilities in support of nuclear weapons manufacturing are not included here since such waste is disposed of at government sites. It is also common practice for government institutions to secure commercial services for their waste disposal needs. Waste brokers provide waste containers, packaging materials and shipping documents, and make the necessary arrangements for transportation and disposal. Government institutions addressed in this report are those that are licensed under Nuclear Regulatory Commission and Agreement State laws governing the possession of radioactive materials. Finally, the database codes identifying government generators do not provide the means to categorize them by types of government agencies or facilities.

In reviewing the information that follows, the reader is cautioned to the fact that the database, on which this characterization is based, incorporates some inherent limitations that must be recognized before reaching any conclusions. Some of these limitations are associated with generator disposal practices, while others are due to differences in how the data are coded and maintained by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

4.2 Characterization of Government Waste Generator Activities

Low-level radioactive waste produced by governmental institutions is generally associated with a broad range of activities. As with other waste generators, the activities that produce waste may change with the implementation of new research programs, assignment of new missions, legislative mandates or grants, etc.

Government facilities primarily obtain radioactive materials from commercial suppliers, but other sources include government research reactors and accelerators generally producing smaller quantities of short-lived radionuclides. Once generated, waste is stored on site and then shipped for disposal. Arrangements for waste transportation and disposal are made directly by the facility or through a waste broker. Some government waste generators exclusively use brokers for all of their radioactive waste disposal needs. Chapter 8 presents a characterization of waste handled by waste brokers and processors.

4.2.1 Waste Streams and Forms

Waste generated by government institutions include solid materials, liquid scintillation fluids, aqueous and organic liquids, biological tissues, compressible and non-compressible materials, liquids (aqueous and oil) stabilized in absorption or solidification agents, solidified evaporator bottoms and chelates, various types of filter media, sealed sources, activated metals and concretes, and gases (NRC81a, NRC81b, NRC82, NRC86a, NRC90, NRC92, DOE87, DOE90a, EGG90, EPA88). In many respects, waste generated by government institutions is similar to that generated by academic facilities. 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, and
- activated and contaminated hardware and concrete.

A key factor in characterizing low-level waste is its physical and chemical form. The concern regarding waste forms stems from NRC requirements that are intended to protect the health and safety of personnel and ensure the long-term stability of the disposal site. Generators are disposing Class A waste using various agents to enhance its stability, even though 10 CFR Parts 61.55 and 61.56 do not require it, unless it is commingled with

Class B or C waste. Disposal sites have followed through by identifying and coding such waste as "stable" or "unstable." A list of approved solidification and sorbent agents is given in Section 2.2, Table 2-7.

4.2.2 Radionuclides and Volumes of Waste Shipped for Disposal

As with other waste generators, government institutions use a wide variety of radionuclides which eventually end up in waste. The selection of a specific radionuclide depends upon the types of research activities or process, methods applied to introduce the radioactivity, and technique used to measure the outcome of a process or procedure. Longer-lived radionuclides found in waste are produced by research reactors and naval propulsion reactors, while short-lived nuclides (e.g., I-123) are produced by particle accelerators. 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.

Table 4-1 lists these radionuclides arranged by half-lives. This listing is based on the radionuclides most often cited by the three low-level waste disposal sites (EGG90, NRC90). Of the 12 nuclides listed, only 1 is characterized by a half-life of less than 100 days and 2 with half-lives of less than 1 year. The balance have half-lives greater than one year, and five have half-lives greater than 100 years.

Table 4-1 Principal Waste Radionuclides Reported by Government Institutions[a]

	<100 Days	<1 Year	>1 Year	>100 Years
	Co-58	Mn-54	H-3	C-14
		Po-210	Pm-147	Ra-226
			Co-60	Th-232
			Fe-55	U-238
			Kr-85	Ni-63
n=	1	2	5	5
%=	7.6	15.4	38.5	38.5

Waste volumes and activities shipped by government institutions are shown in Table 4-2 for 1987 to 1990 (NRC90). Government institutions are responsible for 10.5 to 15.1 percent of the total waste volume, compared to institutional and industrial waste generators (not including nuclear utilities). Waste volumes shipped for disposal range from 2,290 to 3,750 m^3. Over the 4 years reported, waste generation rates have been relatively stable, varying by only about 30 percent. Waste characterized by the presence of chelating agents in concentrations greater than 0.1 percent by weight amounted to about 0.64 and 3.9 m^3 in 1988 and 1989, respectively (NRC90). Data were available only for those two years.

Table 4-2 also indicates that, depending on the year, government institutions make up 7.8 to 20.5 percent of the total activity produced by institutional and industrial facilities (i.e., all waste except that from nuclear utilities). The activity shipped for disposal ranges from 4,900 to 12,600 Ci and reached its highest level in 1989. The data show that government institutions are second in waste volumes and activity levels when compared to industrial, academic, and medical facilities.

Waste volumes for each Compact and unaffiliated State are shown in Table 4-3 based on waste shipments received at the three disposal sites from 1986 to late 1990. Over 90 percent of the total waste volume is generated by six regions. In decreasing order, these are the Southeast, Appalachian, the State of Texas, Northwest, Midwest, and Southwest regions. The balance of the Compacts and unaffiliated States typically generate individually less than 3 percent each.

Table 4-3 also shows the activity shipped for disposal by government waste generators and different regions from 1986 to late 1990 (NRC90, DOE90b). Nearly 83 percent of the total waste activity is generated by four regions. In decreasing order, these are the Appalachian, Southeast, Texas, and Southwest regions. The balance of the Compacts and unaffiliated States typically generate individually less than four percent each.

4.3 Detailed Characterization of Waste Properties

The detailed characterization of government waste is based on information obtained from the National Low-Level Waste Management Program database, known as "MIMS," MIMS on-line service, and the periodic State-by-State Assessment reports published by EG&G Idaho, Inc. Low-level waste data were made available in electronic files from EG&G Idaho, Inc. (MUN90, MUN91) for all three disposal sites.

Table 4-2 Yearly Activity and Waste Volumes Shipped for Disposal Directly by Government Institutions and Percentage of the Waste Shipped by Other Institutional and Industrial Waste Generators (Excluding Nuclear Utilities)[a]

Year		Government	Total (Excluding Utilities)
1986	Volume (m^3)	2.29E+3	2.18E+4
	Percent	10.5	100
	Activity (Ci)	4.90E+3	6.32E+4
	Percent	7.8	100
1987	Volume (m^3)	3.75E+3	2.48E+4
	Percent	15.1	100
	Activity (Ci)	7.17E+3	4.98E+4
	Percent	14.4	100
1988	Volume (m^3)	2.47E+3	1.75E+4
	Percent	14.1	100
	Activity (Ci)	9.49E+3	4.62E+4
	Percent	20.5	100
1989	Volume (m^3)	3.22E+3	2.21E+4
	Percent	14.6	100
	Activity (Ci)	1.26E+4	1.41E+5
	Percent	8.8	100
1990	Volume (m^3)	2.05E+3	1.42E+4
	Percent	14.5	100
	Activity (Ci)	1.01E+4	1.14E+5
	Percent	8.9	100
Total			
	Volume (m^3)	1.38E+4	1.00E+5
	Percent	13.8	100
	Activity (Ci)	4.43E+4	4.18E+5
	Percent	10.6	100

(a) Includes Class A, B, and C brokered and unbrokered waste shipments. Data extracted from NUREG-1418 (NRC90) and on-line DOE/EG&G MIMS, and the 1989 State-by-State Assessment (EGG90). 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 4-3 Government Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 to 1990[a]

	Volume		Activity	
Compact/State	Vol. (m^3)	Percent	Act. (Ci)	Percent
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. Includes 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 for 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.

The electronic files supplied contain manifest LLW data at the shipment level for 5 years, 1986 to 1990. However, data at the container level were available only for Beatty and Richland from 1988 to 1990. In both cases, the 1990 data reflect information posted by the end of November 1990. This information was also supplemented by data obtained through direct access to the MIMS system.

A description of the program, discussion on data manipulation and selection, and validation process are provided in Section 2.0 and Appendix B. Sample copies of shipping manifest forms can be found in Appendix A.

4.3.1 Waste Characterization - Container Level

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

- 78 shipping manifests
- 3,297 container records
- 1,490 cubic meters of waste
- 1.01E+6 kg of waste, 0.68 g/cm^3 average density
- 34.7 Ci of total activity, 0.023 Ci/m^3

Table 4-2 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered and Classes A, B and C, generated from 1988 to 1990 was 7,740 cubic meters and 32,190 Ci, respectively. Accordingly, this search represents over 19 percent of the volume and over 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 captured because over 95 percent of the activity in low-level waste is contained in Class B and C waste, which comprises about five 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 academic waste is about 4.2 Ci/m^3.

Appendix C reveals that the container-level data for government institutions is limited to waste shipped predominantly from the Northwest and Southwest Compacts and does not include waste from the government waste generators located in the East. Accordingly, the available Class A container-level data for government waste may not be representative of all Class A containers. However, the sort has captured the majority of the Class A government waste for the Northwest and Southwest Compacts from 1988 to 1990 and is representative of these Compacts. The portion not captured by the sort is the brokered waste, for which data are available only at the shipment level.

Exhibit 4-1 presents the concentration distributions of the principal radionuclides contained in the 3,297 containers captured by the sort. 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) Median	Average	1%ile	10%ile	90%ile	99%ile
Fe-55	700	1.3E+01	2.8E-04	4.54E-03	4.7E-06	3.85E-05	5.24E-03	9.0E-02
Co-60	700	1.3E+01	2.7E-04	4.50E-03	4.7E-06	3.77E-05	5.16E-03	9.0E-02
Co-58	700	3.0E+00	1.9E-05	2.51E-04	4.7E-06	4.71E-06	2.97E-04	4.7E-03
H-3	40	2.4E+00	3.0E-03	2.58E-03	2.3E-04	6.78E-04	3.39E-03	4.0E-03
Mn-54	700	2.2E+00	5.2E-05	7.86E-04	4.7E-06	9.42E-06	9.09E-04	1.6E-02
Ni-63	3.5*	6.5E-01	1.9E-05	2.75E-04	4.7E-06	4.71E-06	2.97E-04	4.9E-03
C-14	0.8**	3.0E-01	9.4E-06	1.88E-04	4.7E-06	4.71E-06	1.79E-04	2.2E-03
	Total	3.46E+01						

* If contained in activated metals, the limit is 35 Ci/m^3.
** If contained in activated metals, the limit is 8 Ci/m^3.

Though the sort captured 51 radionuclides, the activity of the radionuclides listed above constitutes 34.6 of the 34.7 Curies (or nearly 100%) captured by the sort.

The results indicate that the average radionuclide concentrations for the principal radionuclides are on the order of 10^{-3} to 10^{-4} Ci/m^3. Interestingly, 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, i.e., equivalent to 4.7E-06 Ci/m^3 for a 55-gallon drum.

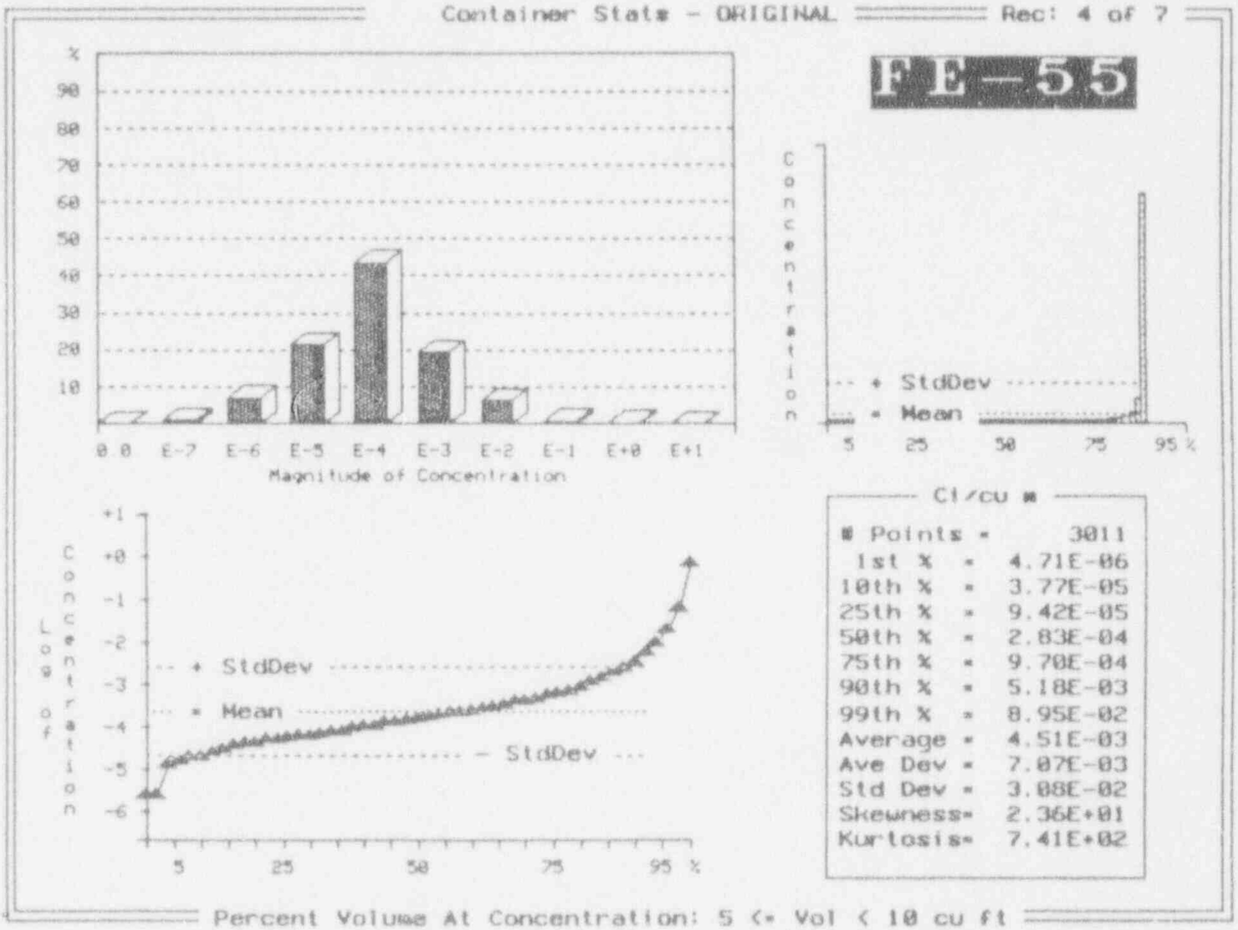
Appendices C and D present all the non-brokered, Class A container-level data sorted by Compact or unaffiliated State and waste stream. Using the data obtained from Appendix C, Table 4-4 compares selected radionuclide concentration distributions of specific waste streams for different regions of the United States. The results indicate that the radionuclide concentrations in resins and filter media are often several orders of magnitude higher than the concentrations of the same radionuclides in other waste streams. In addition, the Fe-55 and Co-60 concentrations are identical, probably because Co-60 is used as a surrogate (by applying a scaling factor) for the hard to measure Fe-55. The results indicate that large differences exist in the concentration of specific radionuclides as a function of waste stream. This result is indicative of the great variety of waste generation practices at government facilities.

EXHIBIT 4-1

GOVERNMENT WASTE - CONTAINER LEVEL ANALYSIS

Number of shipping records captured:	78
Number of container records captured:	3,297
Number of isotope records captured:	18,821
Total activity of containers (Ci):	3.47E+01
Total volume of containers (m^3):	1.49E+03
Total weight of containers (kg):	1.01E+06
Total density (g/cm^3):	6.79E-01
Total concentration (Ci/m^3):	2.33E-02
Total concentration (pCi/g):	3.43E+04

Exhibit 4-1 (Continued)



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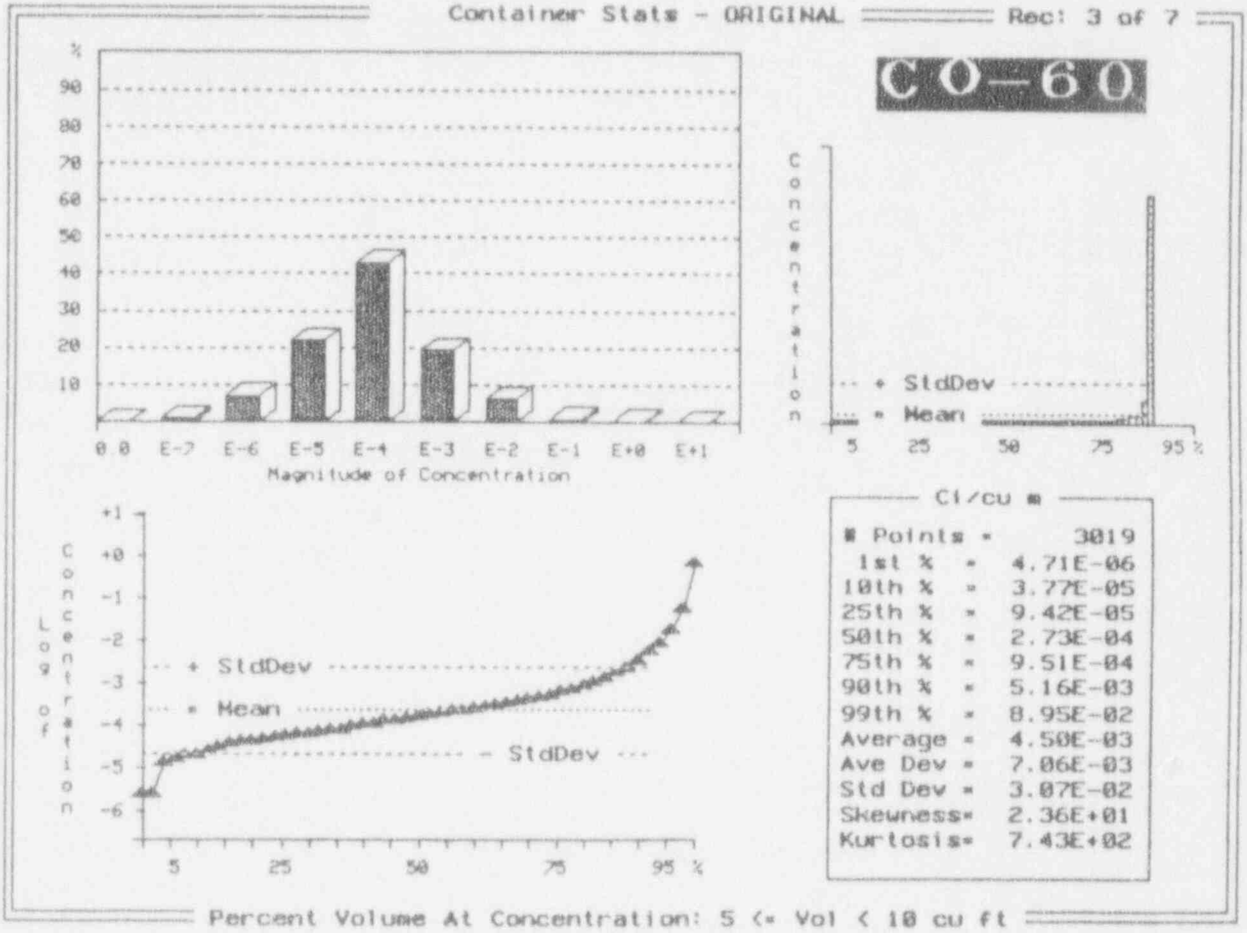

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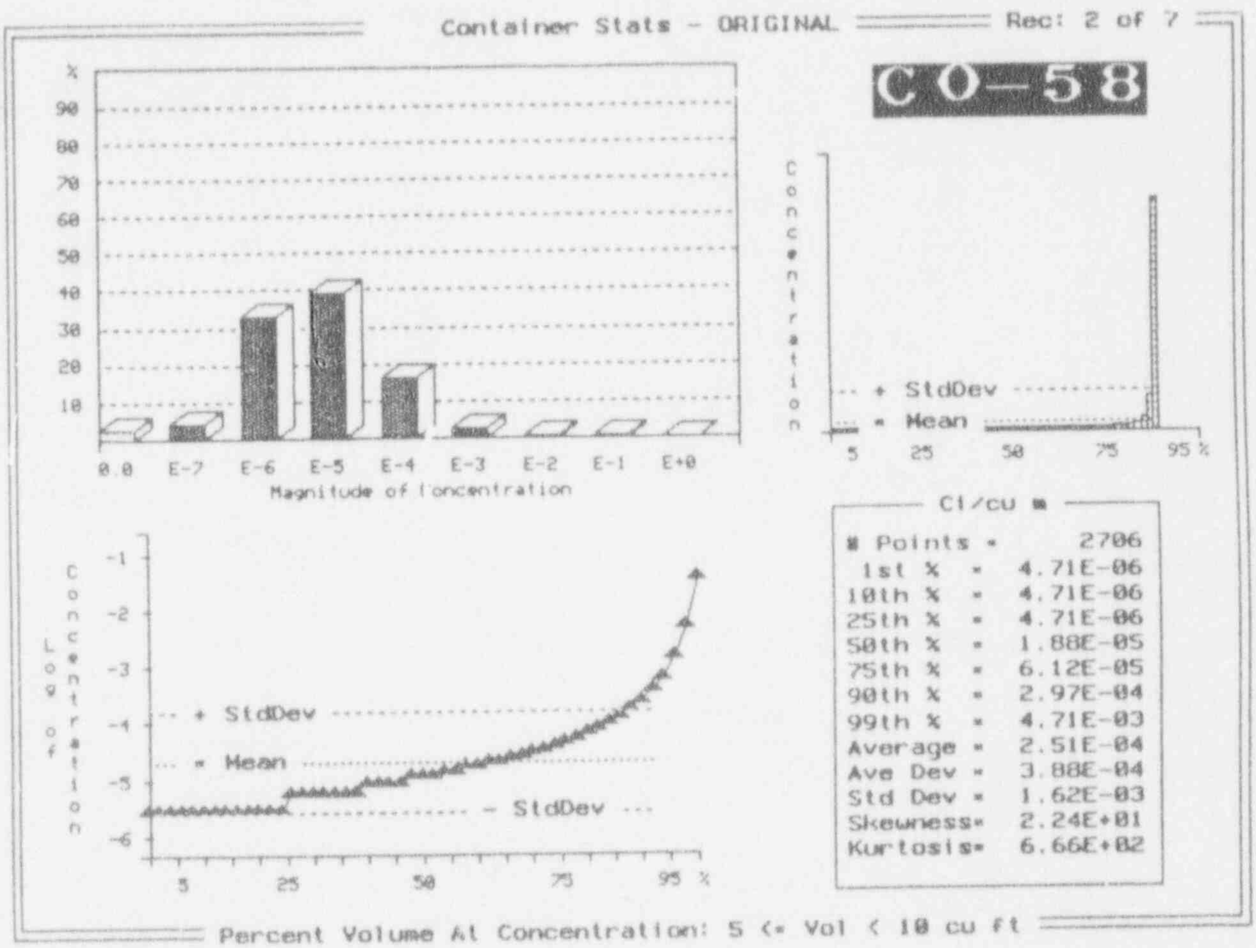

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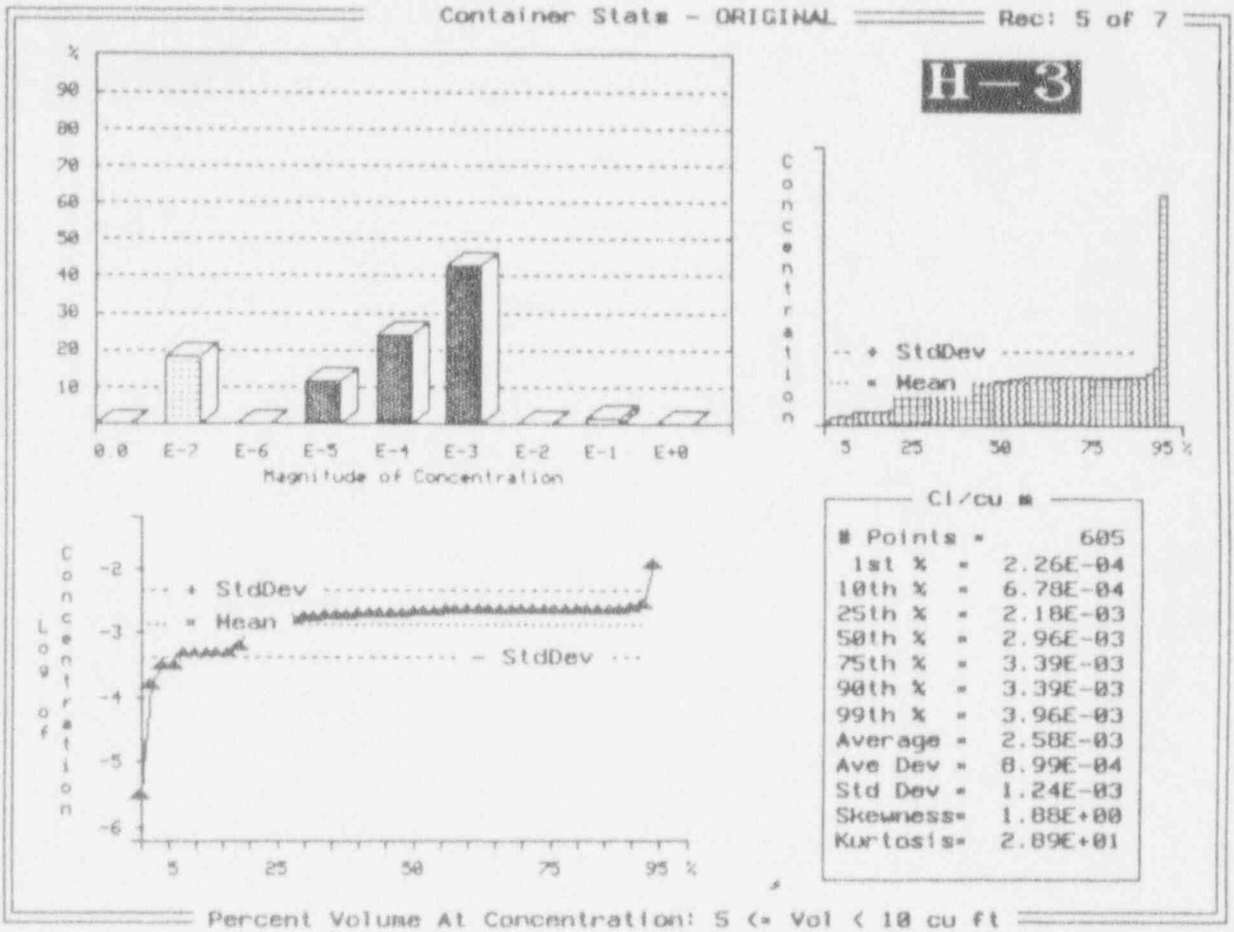

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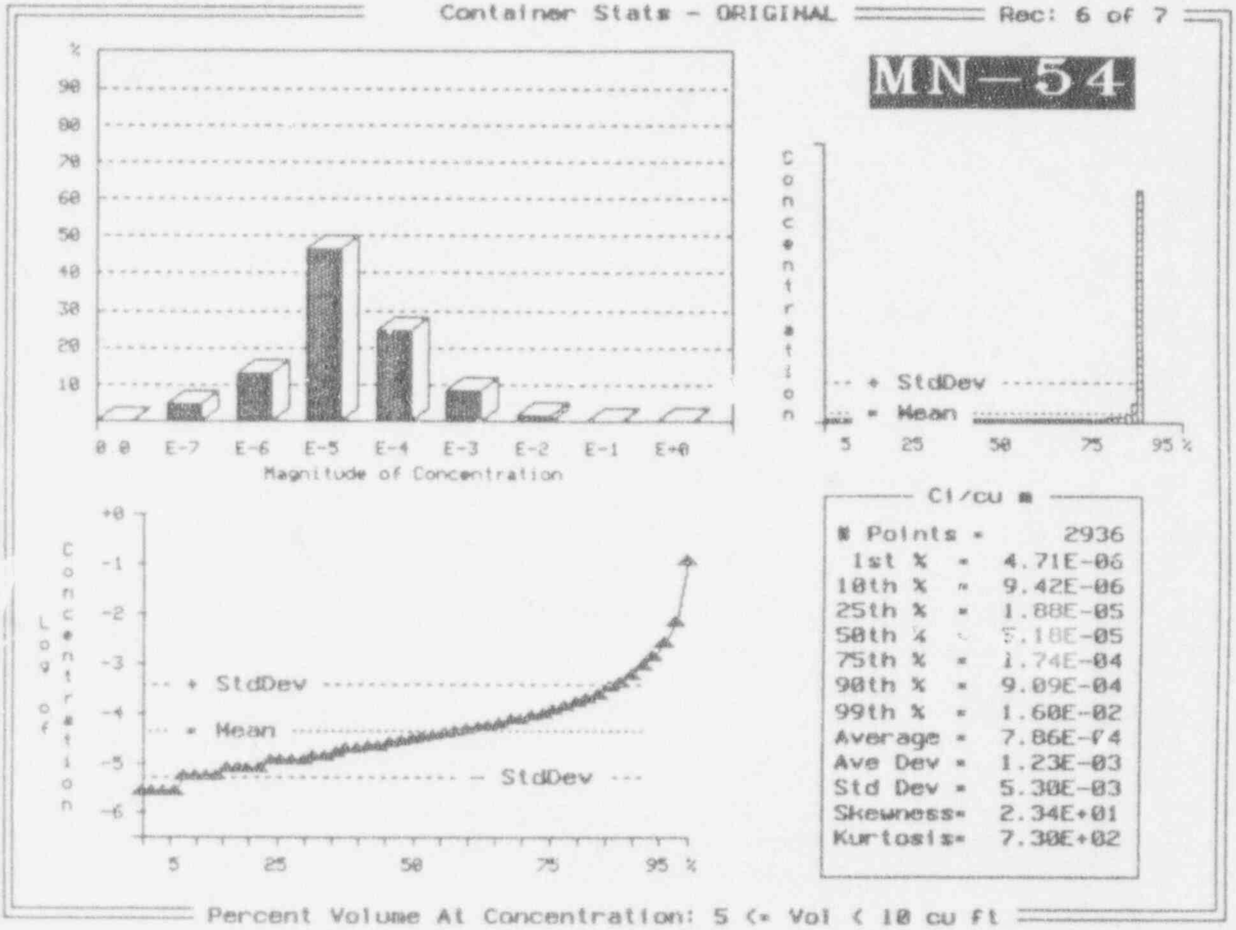

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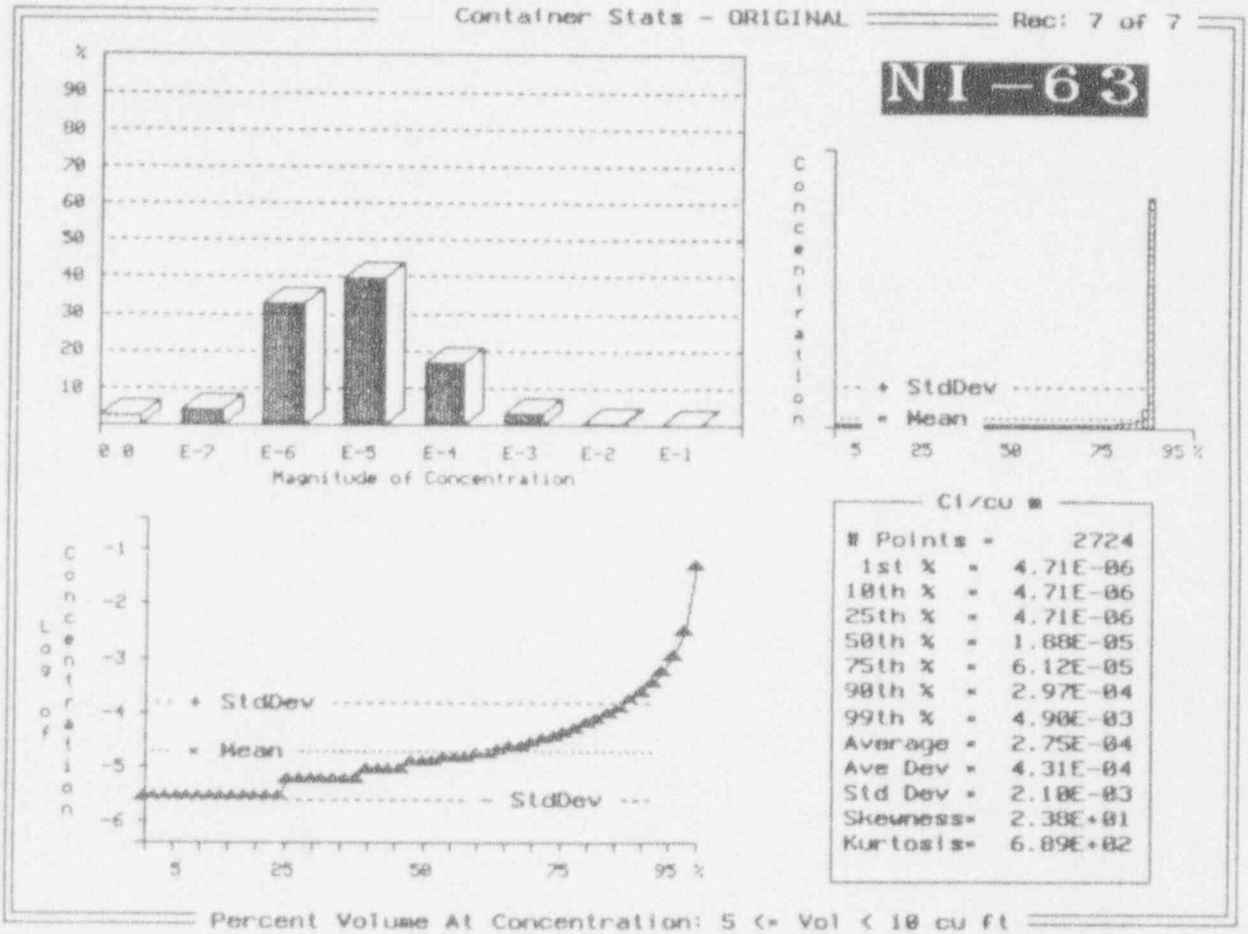

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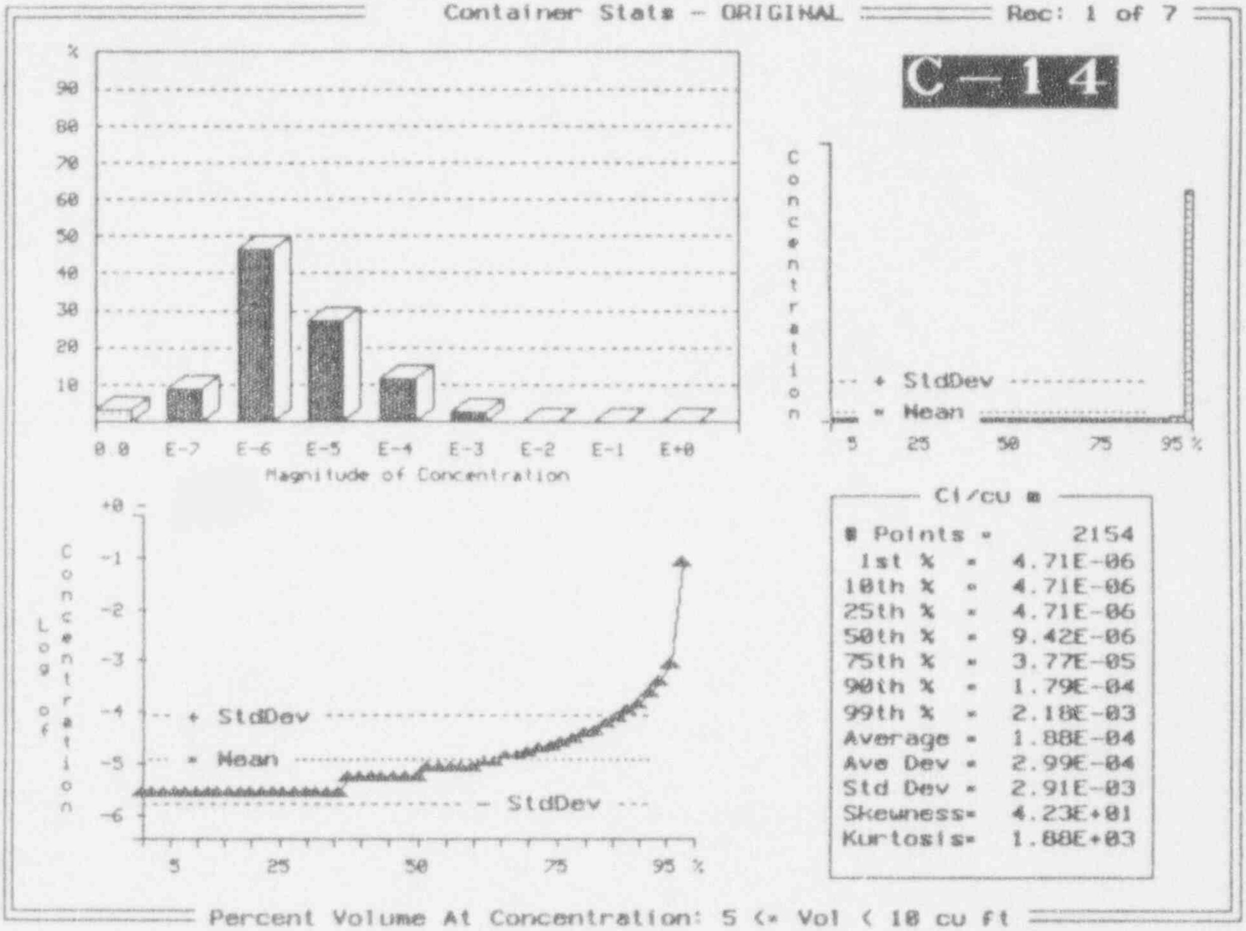


Table 4-4

Comparison of Radionuclide Concentration Distributions in Container-Level Government Waste

	Radionuclide (Ci/m^3) - Percentile											
	Fe-55			Co-60			Co-58			H-3		
	1	50	99	1	50	99	1	50	99	1	50	99
Aggregate	4.7E-6	2.8E-4	9.0E-2	4.7E-6	2.8E-4	9.0E-2	4.7E-6	1.9E-5	4.7E-3	2.3E-4	3.0E-3	4.0E-3
Northwest												
Solidified Resins	1.3E+0	1.3E+0	3.9E+0	1.3E+0	1.3E+0	4.0E+0	6.0E-2	6.0E-2	2.0E-1	6.0E-4	6.0E-4	1.2E-3
Dewatered Resins	1.4E+0	1.4E+0	1.4E+0	1.4E+0	1.4E+0	1.5E+0	7.2E-2	7.2E-2	7.3E-2	6.6E-4	6.6E-4	6.6E-4
Dry Solid	4.7E-6	2.7E-4	7.9E-2	4.7E-6	2.7E-4	7.8E-2	4.7E-6	1.9E-5	4.4E-3	4.7E-6	2.7E-3	1.7E-2
Solidified Liquids	4.7E-6	2.1E-4	4.4E-2	4.7E-6	2.2E-4	4.4E-2	4.7E-6	1.4E-5	2.2E-3	2.3E-4	3.4E-3	3.4E-3
Compacted DAW	3.8E-5	3.8E-4	5.2E-3	3.7E-5	3.4E-4	5.2E-3	4.7E-6	1.9E-5	2.6E-4	2.3E-4	4.5E-4	6.8E-4
Noncompacted DAW	3.4E-5	9.2E-5	6.8E-2	3.4E-5	9.2E-5	6.8E-2	1.9E-6	4.8E-6	3.4E-3			
Noncartridge Filter Media	3.0E-3	4.5E-3	6.2E-2	3.0E-3	4.5E-3	6.2E-2	1.6E-4	2.3E-4	3.1E-3	1.3E-3	2.7E-3	2.9E-3
Southwest												
Noncompacted DAW	1.4E-6	3.4E-4	2.1E-2	1.4E-6	3.4E-4	2.1E-2	7.5E-8	1.7E-5	1.1E-3	1.1E-3	1.1E-3	1.5E-3
Evap. Bottoms Cem.	9.4E-5	4.1E-3	2.3E-2	9.4E-5	4.1E-3	2.3E-2	4.7E-6	2.1E-4	1.2E-3	1.8E-3	2.5E-3	2.5E-3
Sol. Resins Cem.	9.4E-5	1.1E-3	3.3E-1	9.4E-5	1.1E-3	3.3E-1	4.7E-6	5.7E-5	1.7E-2	4.1E-4	2.9E-3	4.7E-3
Compacted DAW	3.8E-5	3.0E-4	4.1E-2	3.8E-5	3.0E-4	4.1E-2	4.7E-6	1.9E-5	2.1E-3	4.1E-4	2.5E-3	4.0E-3
Sol. Liquids Cem.	9.4E-5	1.2E-3	1.8E-2	9.4E-5	1.2E-3	1.8E-2	4.7E-6	6.1E-5	9.2E-4	3.6E-4	9.0E-4	3.1E-3
Dry Solid	9.4E-5	9.4E-5	9.4E-5	9.4E-5	9.4E-5	9.4E-5				1.7E-5	1.7E-5	1.4E-4
Noncartridge Filter Media	9.4E-5	5.1E-4	1.5E-1	9.4E-5	5.1E-4	1.5E-1	4.7E-6	2.4E-5	7.4E-3	4.5E-4	2.2E-3	3.1E-3

A detailed characterization of waste forms at the container level is provided in Appendix C. Each table presents the following information: waste class, waste stream and stabilization agent (if cited by the generator), number of shipping and container records captured by the sort, total waste volume and mass, and average waste form density. Each sort presented in Appendix C is based on varying numbers of waste shipments (up to 46) and containers (up to 1,935), depending on the Compact or State and the waste stream captured by the sort. In all cases, the analyses are based on information contained in the Beatty and Richland database from 1/1/88 to 11/30/90. The data shown in these tables describe the properties of waste shipped directly (i.e., non-brokered) to the disposal sites. Waste shipped by brokers or waste processors do not contain information at the container level that can be assigned to a specific category of waste generators.

The data searches yielded the following waste streams: dry solids, compacted and non-compacted dry active materials, solidified liquids, solidified and dewatered resins, non-cartridge filter media, and evaporator bottoms. In addition, some government generators may at times produce decontamination and decommissioning waste, and activated or contaminated reactor hardware and concrete. Typically, such waste includes dry solids, and compacted and non-compacted dry active materials. The database, however, does not identify waste associated with such activities.

A review of the results presented in Appendix C indicates that, when compared to the list of radionuclides shown in Table 4-1, more nuclides are routinely being cited by government waste generators. These radionuclides include H-3, C-14, Na-22, Mn-54, Cr-51, Fe-55, Fe-59, Co-56, Co-58, Co-60, Ni-63, Zn-65, Kr-85, Sr-90, Zr-95, Tc-99, Ag-110m, I-129, Ba-133, Cs-134, Cs-137, Pm-147, Ir-192, Tl-204, Po-210, Ra-226, Th-232, U-238, and Am-241. This listing comprises over 90 percent of the isotopes typically cited by government generators and makes up over 99 percent of the activity shipped to the disposal sites. Radionuclides that are infrequently reported or that make up relatively lower waste activity levels include, for example, uranium and plutonium and their isotopes, natural uranium and thorium, depleted uranium, antimony, europium, platinum, bismuth, lead, tantalum, zirconium, transuranics (TRU), etc.

The results reveal that radionuclide concentrations routinely vary over six orders of magnitude. Mass concentrations vary from about 1.0 pCi/g to as high as 10^6 pCi/g. Except for a few nuclides, most concentrations tend to fall within a narrower range of 10^2 to 10^4 pCi/g. However, a few radionuclides, e.g., C-14, Fe-55, Co-57, and Pm-147, tend to be characterized by higher concentrations on the order of 10^5 to 10^6 pCi/g.

4.3.2 Waste Characterization - Shipment Level

Each Compact region and unaffiliated State were analyzed for the purpose of characterizing radionuclide distributions at the shipment level. As noted earlier, the data at the shipment level do not provide the means to sort by waste stream or form. The analyses characterize aggregate radionuclide concentrations over the entire waste volume and weight of the shipment. The analyses are based on all shipment data from the three disposal sites and for all years (1/1/86 to 11/30/90).

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

- 242 shipping manifests
- 4,120 cubic meters of waste
- 2.89E+06 kg of waste, 0.70 g/cm^3 average density
- 758 Ci of total activity, 0.18 Ci/m^3

Table 4-3 reveals that the total volume and Curie inventory of all waste shipments, both brokered and unbrokered and Classes A, B and C, generated from 1986 to 1990 was 13,471 cubic meters and 44,707 Ci, respectively. Accordingly, this search represents nearly 31 percent of the volume (the remaining volume was shipped by brokers and a very small portion is Class B and C waste) and 1.7 percent of the activity of the waste shipped for disposal by government waste generators. In addition, the average gross radionuclide concentration in the sort is about 0.184 Ci/m^3, while the average gross radionuclide concentration in all government waste is about 3.3 Ci/m^3.

The overall shipment-level radionuclide concentration results are a factor of eight higher than that of the container-level analysis, which raises questions regarding the representativeness of the container-level data.

This inconsistency might be due to various causes, e.g., 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 raise the overall radionuclide concentration. The database does not provide the means to identify or trace the source of such discrepancies.

Exhibit 4-2 presents the concentration distributions of the principal radionuclides contained in the shipments captured by the sort. The sorts were grouped into the following categories of shipment sizes:

- <10 cubic feet per shipment
- 10 to 50 cubic feet per shipment
- 50 to 100 cubic feet per shipment
- 100 to 500 cubic feet per shipment
- 500 to 1,000 cubic feet per shipment

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides present in 500 to 1,000-cubic foot shipment size category. This category contains the majority of the waste volume and activity:

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.
H-3	40	6.1E+02	2.1E-04	3.7E-03	3.6E-07	2.1E-05	1.0E-03	7.5E-02
Co-60	700	4.8E+01	1.4E-03	4.0E-03	1.9E-06	3.8E-04	6.4E-03	4.6E-02
Fe-55	700	4.8E+01	1.3E-03	3.8E-03	7.7E-06	3.4E-04	5.6E-03	4.6E-02
Mn-54	700	8.2E+00	2.5E-04	7.4E-04	7.4E-07	5.2E-05	1.1E-03	7.8E-03
Co-58	700	5.4E+00	7.7E-05	3.2E-04	2.9E-06	2.0E-05	3.9E-04	7.6E-03
C-14	0.8*	3.7E+00	3.2E-05	8.8E-04	7.4E-07	7.8E-06	3.6E-04	2.7E-03
Ni-63	3.5**	2.6E+00	7.6E-05	2.7E-04	7.0E-07	1.7E-05	5.3E-04	3.5E-03
	Total	7.26E+02						

* If in activated metal, the limit is 8 Ci/m^3.
** If in activated metal, the limit is 35 Ci/m^3.

Though the sort captured 85 radionuclides, the activity of the seven radionuclides listed above constitutes 726 of the 758 Curies (or 96%) captured by the sort.

The shipment-level data were also sorted by Compact and unaffiliated State to determine the degree to which the radionuclide concentration distributions vary regionally. The detailed results of these sorts are shown in Appendix E. Table 4-5 summarizes these results for the key radionuclides. The results reveal that at the 50th percentile level, the aggregate radionuclide concentrations for the principal radionuclides at the container-level are higher by a factor of five to ten than the concentrations of the same radionuclides at the shipment level. This implies that the container level data are not representative of all government waste shipments. The results also indicate that the variability of the radionuclide concentrations within a region for a given radionuclide is large as compared to the variability among regions.

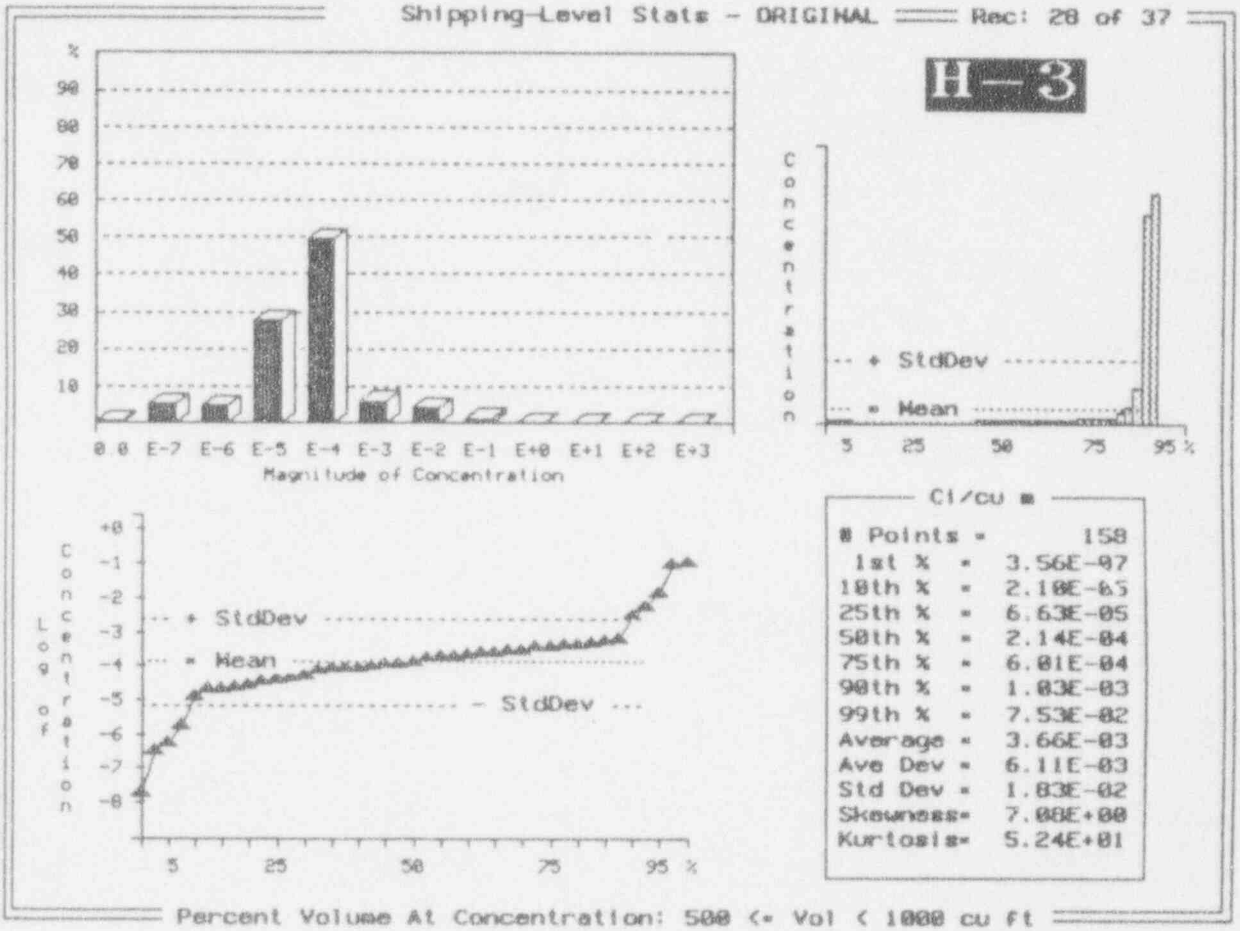
EXHIBIT 4-2

GOVERNMENT WASTE - SHIPMENT LEVEL ANALYSIS

Number of shipping records captured:	242
Number records with container data:	60*
Number of manifests captured:	0
Number of container records captured:	2,591
Number of isotope records captured:	1,877
Total activity of shipment (Ci):	7.58E+02
Total volume of shipments (m^3):	4.12E+03
Computed weight of shipments (kg):	2.89E+06
Total weight of containers (kg):	8.02E+05*
Nominal density (g/cm^3):	7.01E-01
Total density (g/cm^3):	7.16E-01*
Total concentration (Ci/m^3):	1.84E-01
Total concentration (pCi/g):	4.19E+04*

* For shipments with container data.

Exhibit 4-2 (Continued)



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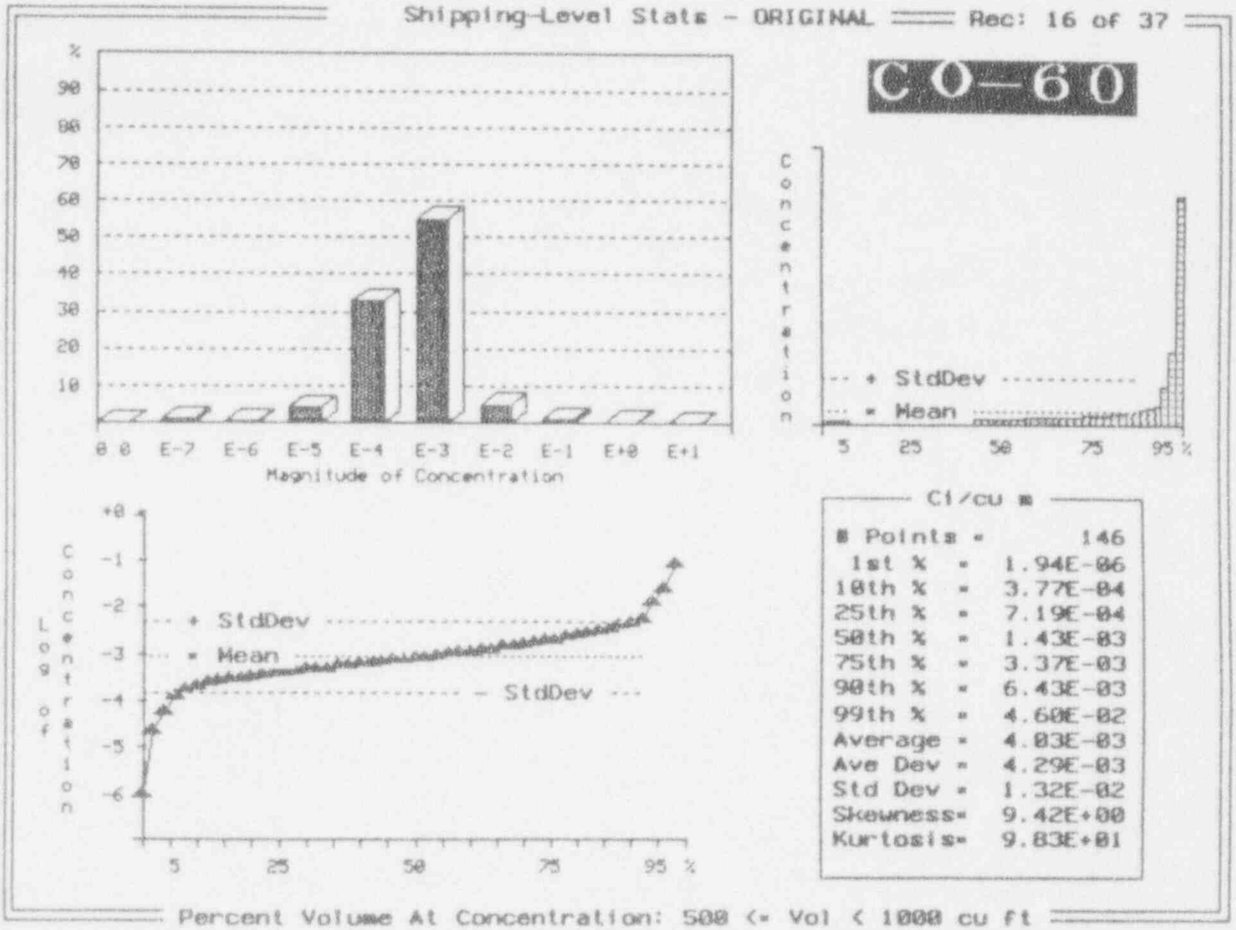

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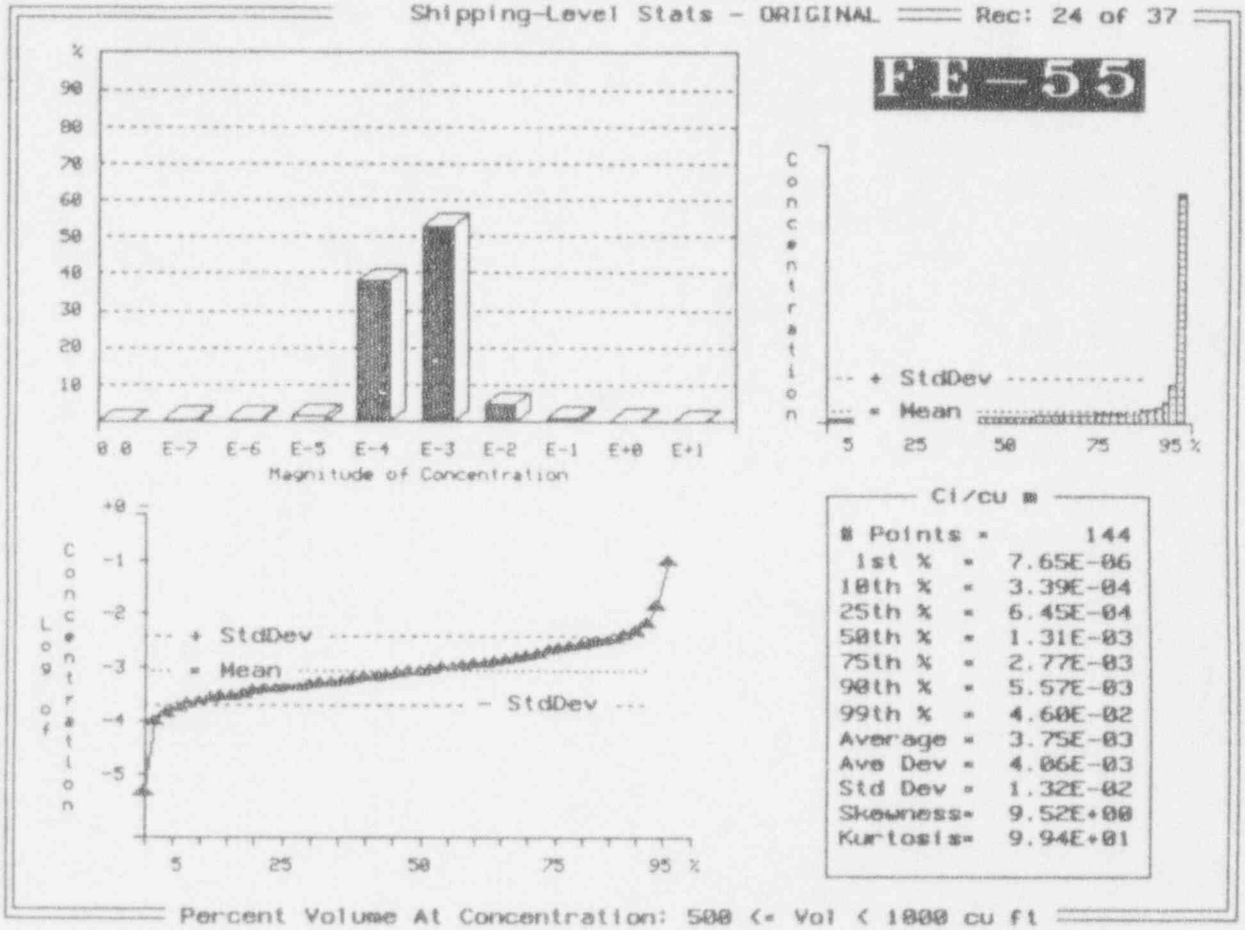

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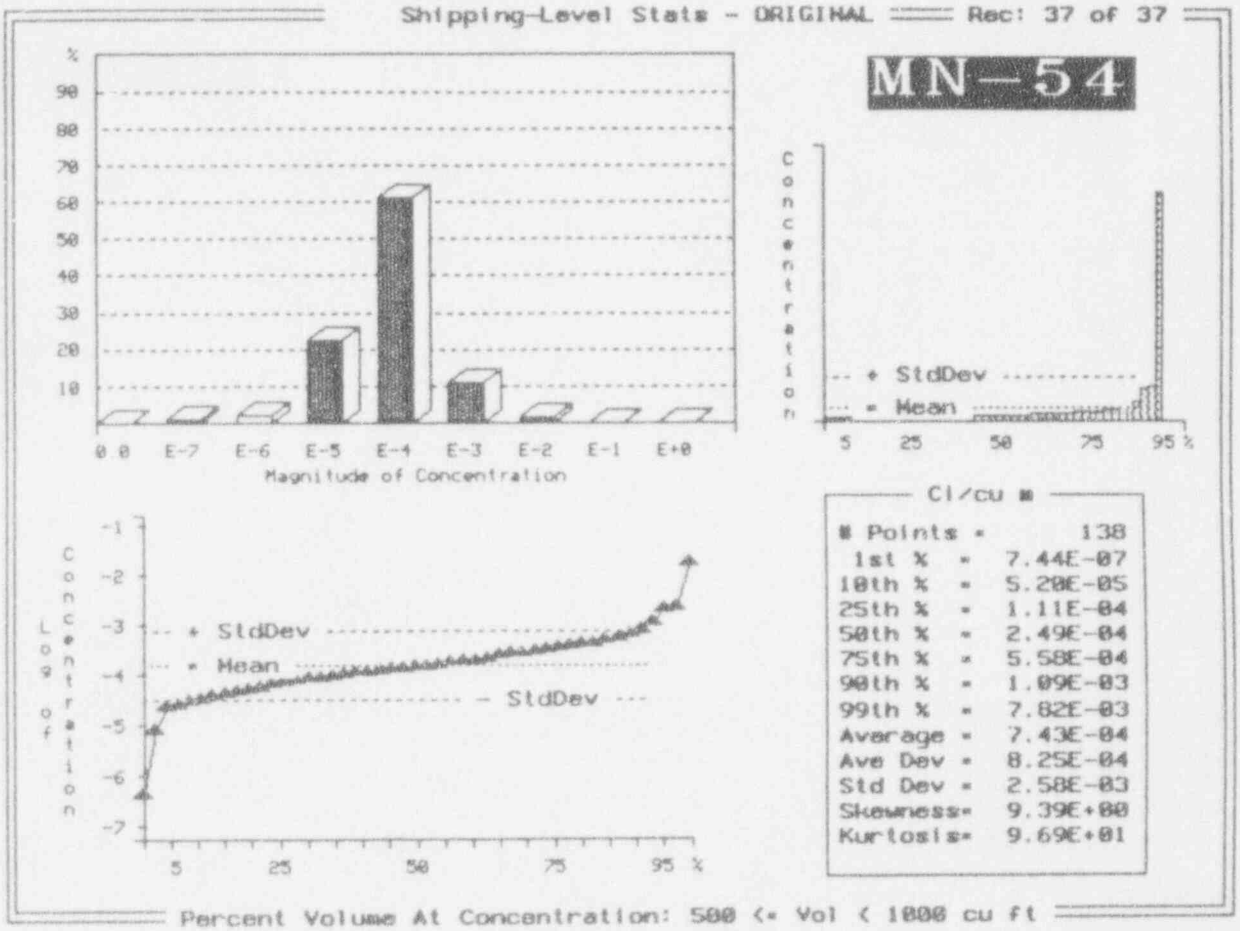

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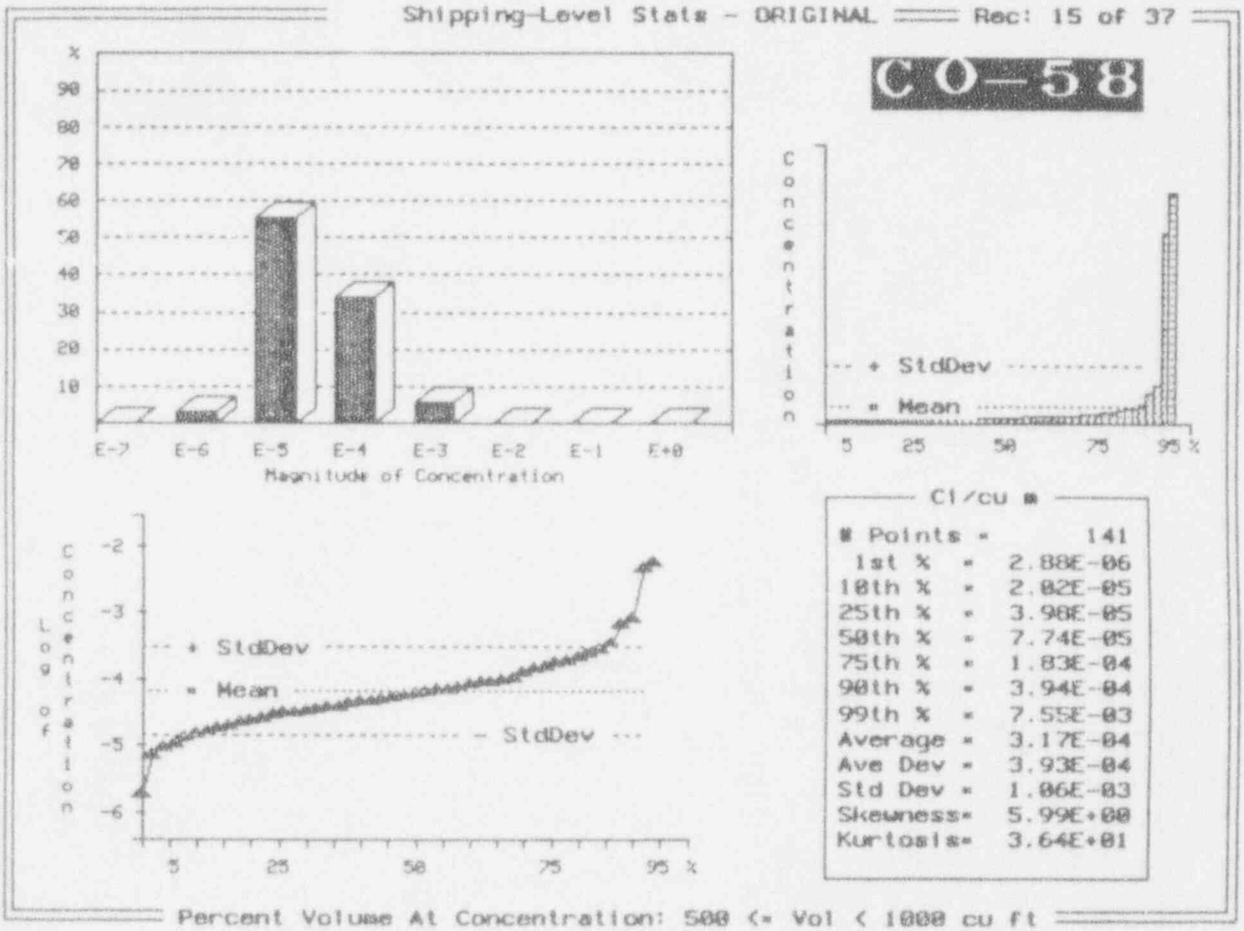

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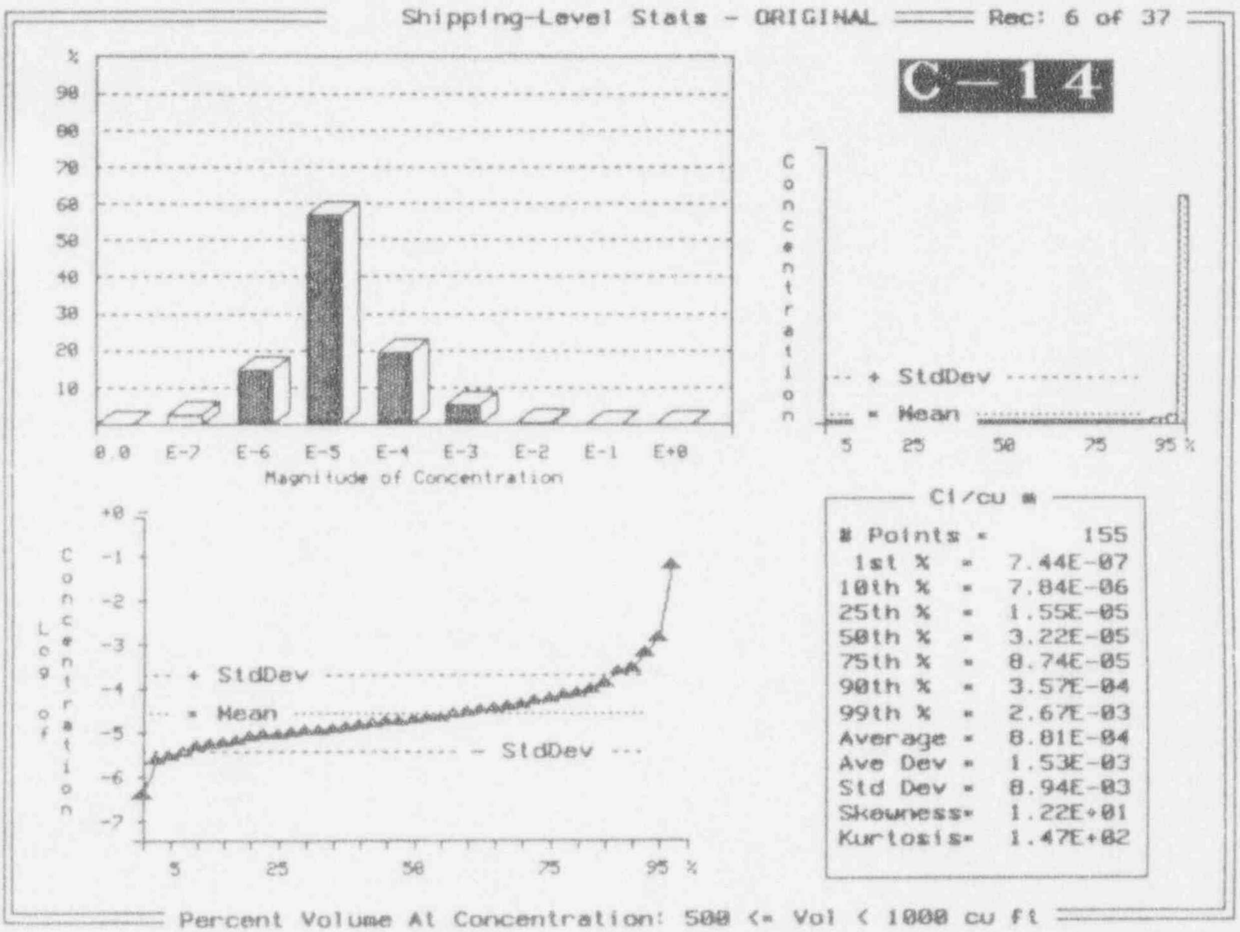

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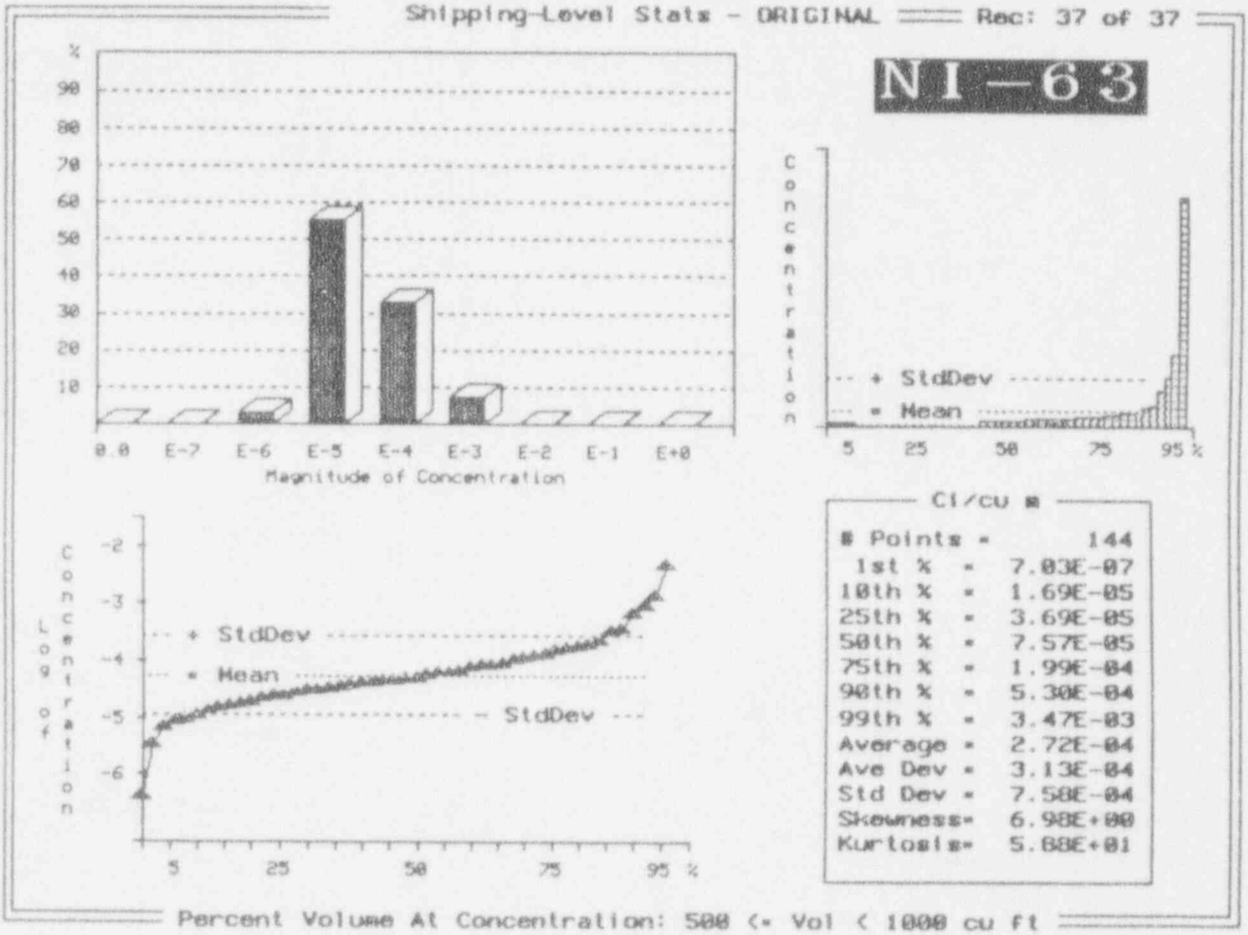


Table 4-5

Comparison of Radionuclide Concentration Distributions at the Shipment Level for Government Waste Generators (1986 to 1990)

	Total Volume (m3)	Volume Captured (m3)	Radionuclide (Ci/m^3) - Percentile											
			H-3			Co-60			Mn-54			C-14		
			1	50	99	1	50	99	1	50	99	1	50	99
Aggregate Container Level			2.3E-4	3.0E-3	4.0E-3	4.7E-6	2.7E-4	9.0E-2	4.7E-6	5.2E-5	1.6E-2	4.7E-6	9.4E-6	2.2E-3
Aggregate Shipment Level			3.7E-7	2.1E-4	7.5E-2	1.9E-6	1.4E-3	4.6E-2	7.4E-7	2.5E-4	7.8E-3	7.4E-7	3.2E-5	2.7E-3
Shipment Level by Region														
Northwest	1,650	1,600	4.2E-8	3.8E-4	5.7E-3	2.9E-5	1.7E-3	4.6E-2	5.0E-6	2.8E-4	7.8E-3	6.2E-7	3.4E-5	9.2E-4
Rocky Mountain	13	0												
Central	36	8.4	Only 1 shipping record											
Midwest	915	43.5	5.2E-3	4.0E-2	7.5E-2							2.4E-3	5.7E-2	1.1E-1
Central Midwest	211	61.3	1.2E-3	1.2E-3	5.1E-2							7.5E-4	7.5E-4	4.8E-3
Southeast	4,950	3,534	3.6E-7	1.4E-4	7.0E-4	3.7E-7	7.2E-4	1.1E-2	7.4E-7	1.3E-4	6.0E-4	4.7E-7	1.7E-5	2.4E-1
Northeast	176	74.2	3.7E-4	3.7E-4	3.9E-4	1.3E-6	1.9E-3	4.2E-3	4.4E-7	3.3E-4	7.2E-4	9.6E-6	5.2E-5	8.4E-5
Appalachian	1,940	410.8	2.6E-4	7.4E-3	2.5E-1	4.7E-6	1.9E-3	7.3E-3				6.6E-5	6.2E-4	3.5E-3
Southwest	914	828.9	2.1E-5	1.2E-4	6.0E-4	3.8E-5	1.4E-3	1.1E-2	6.3E-6	2.4E-4	1.9E-3	7.4E-7	2.8E-5	2.3E-4
DC	29	0												
Maine	368	286.9	3.2E-4	4.4E-4	6.5E-4	1.5E-5	5.6E-4	2.5E-2	2.0E-6	8.6E-5	3.[illegible]E-3	3.8E-6	1.3E-5	5.3E-4
Massachusetts	179	168				1.6E-5	2.7E-4	5.2E-4						
New Hampshire	0.2	0												
Rhode Island	1	0.8												
Texas	1,810	1,743	4.7E-6	3.9E-3	1.1E-2	1.1E-7	1.6E-3	5.6E-3				9.4E-8	8.1E-2	1.6E-1
Vermont	<0.1	0												
New York	279	73.3				1.2E-5	4.2E-5	7.2E-5						

These results are also complemented with histograms and cumulative distribution curves shown in Appendix F. Radionuclide histograms and cumulative distributions are presented only for those nuclides that are consistently reported by waste generators. The results also provide summary sheets providing additional information for each Compact and State, including the associated number of waste generators, total number of shipping records and containers (as is applicable), shipment weights, and total and fractional waste volumes and activity levels.

A review of the data presented in Appendices C and F reveals that the most often cited radionuclides include H-3, C-14, Na-22, Mn-54, Cr-51, Fe-55, Fe-59, Co-56, Co-58, Co-60, Ni-63, Zn-65, Kr-85, Sr-90, Zr-95, Tc-99, Ag-110m, I-129, Ba-133, Cs-134, Cs-137, Pm-147, Ir-192, Tl-204, Po-210, Ra-226, Th-232, U-238, and Am-241. Radionuclide concentrations were observed to vary over 6 orders of magnitude, typically from about 0.1 to 10^5 pCi/g. However, a few nuclide concentrations were observed to range from 10^6 to 10^9 pCi/g (e.g., H-3, C-14, Fe-55, Co-58, Co-60, I-125, and Cs-137). The analyses captured varying waste volumes (from 2 to 97 percent) and activity levels (from <0.1 to 30 percent), depending upon Compact regions or States. These results characterize waste associated with single to multiple shipments (up to 183) and up to 87 waste containers.

4.4 Mixed Waste

Mixed waste, characterized by both hazardous chemical and radioactive properties, are generated during various activities when chemicals are introduced as cleaning agents or solvents. Activities that may result in the generation of mixed waste include R&D, laboratory analyses, and decontamination activities. Furthermore, actual generation rates are highly variable and are dependent upon specific facility practices.

Mixed waste generation rate estimates are based on the results of the National Profile on Commercially-Generated Low-Level Radioactive Mixed Waste (NUREG/CR-5938), as such waste is not being shipped to the disposal sites (NRC92). Consequently, the low-level database does not contain such information. The generation rates were weighted on a national basis to account for facilities which did not respond to the survey and those that were not queried during the survey.

Tables 4-6 and 4-7 summarize the results of the 1990 National Profile for government waste generators. The results indicate that spent scintillation fluids and organics liquid waste make up about 94 percent of the waste volume (see Table 4-6).

Table 4-6 Government Generators Mixed Waste Profile - 1990[a]

Waste Stream	Weighted Annual Generation Rate (ft^3/yr)	Percent
Liquid Scintillation Fluids	20,315	76.7
Waste Oils	4	<0.02
Chlorinated Organics	1,179	4.5
Chlorinated Fluorocarbons	(b)	--
Other Organics	3,525	13.3
Metals (Pb, Cr, and Cd)	301	1.1
Corrosive Materials	1,167	4.4
Other Materials	9	0.03
Total	26,500	(b)

(a) Data extracted from NUREG/CR-5938, Table 4-6 (NRC92).
(b) Result may not add up to 100% due to rounding off.

Table 4-7 summarizes the results of the 1990 National Profile by Compact regions and States. The results indicate that four Compacts and the District of Columbia generate about 94 percent of the estimated waste volume. In decreasing order, they are the Appalachian, Southeast, Central Midwest Compacts, the District of Columbia, and the Midwest Compact. The total mixed waste volume for all regions has been estimated to be 26,500 ft^3 in 1990 (NRC92).

Table 4-7 Academic Institutions - 1990 Regional Mixed Waste Generation Profile[a]

Compact/State	Estimated Volume (ft^3)
Northwest	576
Rocky Mountain	35
Central States	68
Midwest	1,527
Central Midwest	2,892
Southeast	4,438
Northeast	15
Appalachian	14,216
Southwest	206
Maine	(b)
Massachusetts	27
New York	300
Texas	242
Vermont	(b)
New Hampshire	(b)
Rhode Island	(b)
District of Columbia	1,958
Puerto Rico	(b)
Total	26,500

(a) Data extracted from NUREG/CR-5938, Table 4-10 (NRC92).
(b) No data reported or facilities were not surveyed.

4.5 Government Waste Generators - Class A Waste Description and Characteristics of Typical Government Waste Generators

The purpose of this section is to characterize the volumes, activities, and waste streams of typical government waste generators. This section emphasizes the volume and activity shipped per waste generator, as opposed to the above discussion, which emphasizes activities and volumes for the category as a whole.

4.5.1 Waste Streams and Forms

The types of Class A waste generated by typical government generators include dry solid materials, compacted and non-compacted dry active waste, aqueous waste in vials and sorbents, absorbed and solidified aqueous liquids, solidified oils and non-aqueous liquids, and non-cartridge filter media. These waste streams are routinely produced by the majority of the generators, make up a large fraction of the total waste volume, and have relatively well characterized radiological and physical properties.

4.5.2 Waste Volume

Tables 4-8 and 4-9 present averages, ranges, Class A waste generation volumes, and total number of waste generator identification codes by Compact regions or States. The data characterize overall practices from 1986 to 1990. For example, Table 4-8 indicates that the average government waste generator located in the Northwest Compact produced 70 m^3 of waste over a five year period, from 1986 to 1990. The yearly average generation rate is derived by dividing the tabulated waste volume by 5, or about 14 m^3. Table 4-9 indicates that the waste volume shipped by government generators in the Northwest Compact from 1986 to 1990 varied over six orders of magnitude, from 0.0085 to 1,060 m^3. At the 50th percentile, the aggregate waste volume is 0.114 m^3, for an annual average of 0.023 m^3.

Similar comparisons can be made for the other Compact regions or States. For more details on waste volume distributions, see Appendix F.

These results should be interpreted with caution since the number of waste generators is based on unique identification codes assigned by the disposal sites and does not necessarily reflect the total number of facilities that actually produced the waste.

Table 4-8 Waste Volume Distribution Among Governmental Generators by Compact Regions and States[a]

		-- Waste Volume - m^3[b]		--
Compact/State	No. of Unique Gen. Code	Five-Year Total Vol. All Gen.	Ave. Gen. Five-Year Total Vol.	Ave. Gen. Yearly Volume
Northwest	23	1,613	70	14
Rocky Mountain	15	10	0.7	0.1
Central	12	36	3.0	0.6
Midwest	30	912	30	6.0
Central Midwest	18	211	12	2.3
Southeast	47	4,878	104	21
Northeast	10	171	17	3.4
Appalachian	30	1,936	65	13
Southwest	41	914	22	4.5
District of Columbia	6	29	4.9	1.0
Maine	3	365	122	24
Massachusetts	5	179	36	7.2
New Hampshire	1	0.15	0.15	0.03
New York	19	270	14	2.9
Puerto Rico(c)	--	---	---	---
Rhode Island	2	0.93	0.5	0.09
Texas	6	1,794	299	60
Vermont(c)	--	---	---	---
Total:	268	13,319	800	160
- Low:	1	0.15	0.15	0.09
- High:	47	4,878	299	60
- Average:	17	832	50	10
- Std. Dev.:	14	1,272	76	15

(a) Compiled from data given in Appendix F for all Class A waste forms.

(b) Aggregate and yearly average waste generation rates are rounded off. See text for details. To convert volume to to cubic feet, multiply cubic meter by 35.3.

(c) No waste disposed of during the reported period.

Table 4-9 Government Waste Volume Distributions Per Waste Generator Among Compact Regions and States[a]

Compact/State	Waste Volume (m^3) per Waste Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	8.50E-03	1.14E-01	1.06E+03
Rocky Mountain	1.42E-03	1.13E-01	3.88E+00
Central	2.83E-03	1.39E-01	1.98E+01
Midwest	2.83E-03	2.20E-01	8.42E+02
Central Midwest	8.50E-03	4.33E-01	1.04E+02
Southeast	3.11E-03	1.31E+00	1.12E+03
Northeast	8.50E-03	2.84E-01	1.15E+02
Appalachian	8.50E-03	5.04E-01	1.73E+03
Southwest	5.66E-03	1.05E-01	8.16E+02
District of Columbia	5.13E-02	3.29E+00	1.04E+01
Maine	6.52E-02	7.08E-02	3.65E+02
Massachusetts	8.50E-03	6.18E-02	1.78E+02
New Hampshire	1.46E-01	1.46E-01	1.46E-01
New York	8.50E-03	2.12E-01	2.22E+02
Puerto Rico(c)	---	---	---
Rhode Island	1.42E-02	1.42E-02	9.21E-01
Texas	8.50E-03	3.81E+01	1.45E+03
Vermont(c)	---	---	---

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. See text for details.
(b) Yearly waste generation distributions may be approximated by dividing above values by five. 1 m^3 = 35.3 cubic feet.
(c) No waste disposed of over the reported period.

The number of generators represents all that ever shipped waste from 1986 to late 1990 and does not necessarily reflect the current population size. It is not uncommon for some waste generators to have access to two disposal sites. In such instances, a single generator would have two identification codes. As a result, the total number of waste generators estimated by using their identification codes may be overestimated. Moreover, it is not possible to assess the extent of such practices. The database does not provide the means to identify generators by types of government facilities or agencies.

4.5.3 Radionuclide Distributions and Concentrations

Waste activity distributions are shown in Table 4-10. As can be noted, waste activity levels shipped by individual government generators vary over ten orders of magnitude, from 1 uCi to 14,400 Ci. At the 50th-percentile, aggregate waste activities vary widely as well, spanning six orders of magnitude across all regions. Appendix F presents more detailed information on waste activity distributions.

The most often cited radionuclides include H-3, C-14, Na-22, Mn-54, Cr-51, Fe-55, Fe-59, Co-56, Co-58, Co-60, Ni-63, Zn-65, Kr-85, Sr-90, Zr-95, Tc-99, Ag-110m, I-129, Ba-133, Cs-134, Cs-137, Pm-147, Ir-192, Tl-204, Po-210, Ra-226, Th-232, U-238, and Am-241.

4.6 Geographic Distribution and Demographics of Government Waste Generators

4.6.1 Geographical Distribution

Government waste generators are located in both metropolitan centers and in rural areas. Most government facilities have been involved in various activities since their inception, but it is only relatively recent that some are using radioactive materials. As with other generators, governmental institutions have also expanded by building additional facilities to support new programs. In many instances, such new facilities are built on existing properties or in nearby communities.

The locations of the major government waste generators are identified by city, county, and state (see Appendix G-1). Government waste generators may have more than one location identified under the same NRC and/or Agreement State license. However, it does not follow that all identified locations necessarily generate waste. The information contained in Appendix G-1 was extracted from periodic reports issued by Compacts and States. Some states, however, did not provide this information.

Table 4-10 Government Waste Activity Distributions Per Waste Generator Among Compact Regions and States[a]

Compact/State	Waste Activity (Ci) Per Waste Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	2.70E-05	1.86E+00	7.25E+01
Rocky Mountain	1.00E-06	1.90E-01	9.92E+02
Central	1.60E-05	2.12E+00	2.27E+02
Midwest	7.00E-06	3.60E-01	1.32E+02
Central Midwest	1.00E-06	5.37E-02	8.64E+02
Southeast	4.00E-05	9.64E-02	7.20E+03
Northeast	1.15E-03	5.74E-03	1.46E+03
Appalachian	1.40E-05	7.11E-02	1.44E+04
Southwest	1.00E-06	1.00E-03	1.24E+03
District of Columbia	8.74E-03	7.01E-02	1.04E+01
Maine	5.65E+00	6.39E+00	6.65E+00
Massachusetts	1.00E-06	1.00E-05	1.42E+02
New Hampshire	1.12E+01	1.12E+01	1.12E+01
New York	1.00E-06	1.13E-02	1.68E+02
Puerto Rico(c)	---	---	---
Rhode Island	6.68E-03	6.68E-03	8.49E+00
Texas	1.00E-06	3.33E+00	4.41E+03
Vermont(c)	---	---	---

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. Entries with 0.00E-00 values indicate that the database did not have any data for those records. See text for details.

(b) Yearly waste activity distributions may be approximated by dividing values by five. 1 Ci = 3.7×10^{10} Bq.

(c) No waste disposed of over the reported period.

4.6.2 Demographics

Population data were obtained from the Bureau of Census based on the 1990 census results (DOC92). The data were sorted to tally population counts by Compact, State, and county, when identified. Population data were compiled for each of the nine Compacts and nine unaffiliated States (see Appendix G-2).

5.0 INDUSTRIAL FACILITIES

5.1 Introduction

Industrial facilities include all other commercial generators of low-level waste not characterized under the institutional or utility heading. Industrial facilities are involved in diverse types of activities, such as research, materials testing, chemical production, drug research, clinical testing, mineral exploration and processing, and basic and applied research in various scientific disciplines (e.g., physics, chemistry, medicine, and biology).

Some facilities manufacture consumer products, level and density gauges, instrumentation, and measurement devices that incorporate radioactivity. Industrial facilities also produce radioactive materials that are used as feed stock by other industrial facilities. Such materials include radio-chemicals, radio-pharmaceuticals, sealed radioactive sources, self-luminous signs and markers, fuels for nuclear power plants, and consumer and industrial products. Radioactive materials used by industrial facilities are produced by research reactors and particle accelerators. Some of the radioactive materials are imported from other countries (AME91). Industrial facilities are licensed under Nuclear Regulatory Commission and Agreement State laws governing the possession and use of radioactive materials.

A separate discussion of fuel fabrication facilities is also included in this section due to the relatively well defined and unique nature of this practice and its waste. Fuel fabrication facilities manufacture new fuel for nuclear power plants, provide specialized services during refueling activities, provide specialized equipment, such as shipping casks and refueling tools, and, in some instances, store spent fuel. There are only a few fuel fabrication facilities nationwide.

It is common practice for industrial facilities to secure commercial services for waste disposal, especially those that generate small volumes of waste. Brokers make arrangements for all transportation and disposal needs. Waste brokers and processors are also included in the industrial category, however, they are not included here. Section 8.0 presents a separate discussion on this topic.

In reviewing the information contained in this section, the reader is cautioned that the database incorporates some inherent limitations that should be recognized before drawing any conclusions. Some of these limitations are associated with disposal practices, while others are due to differences in how the data are coded by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

5.2 Characterization of Industrial Waste Generator Activities

This section characterizes low-level waste generated by industrial facilities. A summary characterization of industrial waste is based on information and data contained in published reports. As is noted in Sections 3.0, 4.0, and 6.0, some of the discussions and results noted here also apply to "biomedical" waste generators, i.e., those included in the medical, academic, and governmental sectors.

5.2.1 Waste Streams and Forms

Industrial facilities generate a wide spectrum of waste (EGG90, NRC90, NRC83a, NRC83b, NRC92). Such waste, in decreasing order, includes:

- 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, and
- dewatered resins.

Another important factor in characterizing low-level waste is its physical and chemical form. The concern regarding waste forms stems from NRC requirements meant to protect the health and safety of personnel and ensure the long-term stability of the disposal site. Generators that are disposing Class A waste are using various agents to enhance its stability, even though 10 CFR Parts 61.55 and 61.56 do not require it, unless it is commingled with Class B or C waste. Disposal sites have followed through by identifying and coding such waste as "stable" or "unstable." A list of approved solidification and sorbent agents is given in Section 2.2, Table 2-7.

5.2.2 Radionuclides and Volumes of Waste Shipped for Disposal

Industrial facilities typically use the widest array of radioactive materials. The use of any specific radionuclide depends upon the types of research activities or industrial processes being employed and the techniques used to monitor the processes. The majority of the radionuclides are produced by research reactors, while short-lived nuclides (e.g., I-123, Ga-67) are made by particle accelerators. Some industrial facilities operate their own accelerators and research or test reactors. The most frequently reported radionuclides include H-3, C-14, Co-60, Ra-226, Pu-241, U-238, and natural uranium and thorium (EGG90). A review of the literature, however, indicates that additional radionuclides are being cited by waste generators (NRC90, ICR77, NRC82, NRC87, NRC89b, NRC92). Table 5-1 lists the radionuclides that account for over 99 percent of the total activity shipped in Class A waste.

Waste activity and volumes generated by each Compact and unaffiliated State are shown in Table 5-2 based on waste shipments received at the three disposal sites from 1986 to late 1990. About 99 percent of the total waste activity is generated by nine regions. In decreasing order, these are the States of Massachusetts, the Southwest, Northeast, and Appalachian Compacts, the States of New York and Texas, and the Midwest, Southeast, and Rocky Mountain Compacts. The balance of the Compacts and States generate less than 0.2 percent each.

In terms of waste volumes, over 94 percent of the total waste volume is generated by nine regions (see Table 5-2). In decreasing order, these are the Southeast, Northwest, Central, Southwest, and Appalachian Compacts, the State of Massachusetts, the Midwest, Northeast, and the Central Midwest Compacts, and the State of New York. The balance of the Compacts and unaffiliated States typically generate less than 1.2 percent each.

The activity and volume of waste shipped for disposal by industrial generators and all waste generators (excluding nuclear utilities) is shown in Table 5-3 (NRC90, DOE90b). Table 5-3 indicates that, excluding nuclear power plants, industrial facilities produce the majority of the total activity, 74 to 90 percent. The activity shipped for disposal ranges from 34,400 to 127,0000 Ci. The highest activity levels were shipped in 1989 and 1990.

Table 5-1 Principal Waste Radionuclides Reported by Industrial Waste Generators[a]

<24 hours	<7 Days	<100 Days	<1 Year	>1 Year	>100 Years
I-123	Ga-67	P-32	Ca-45	H-3	C-14
	In-111	S-35	Mn-54	Na-22	Al-26
		Cr-51	Co-57	Co-60	Cl-36
		Co-58	Zn-65	Fe-55	Ni-63
		Fe-59	Ge-68	Kr-85	Tc-99
		I-125	Ag-110m	Sr-90	Ra-226
		I-131	Sn-113	Cd-109	Th-232
			Gd-153	Ba-133	U-234
			Po-210	Cs-134	U-235
				Cs-137	U-238
				Pm-147	Nat-U
					Nat-Th
					Dep-U
n= 1	2	7	9	11	13
%= 2.3	4.6	16.3	20.9	25.6	30.3

(a) See text for details.

In 1989, industrial waste generators produced and shipped 1.051 Ci of solidified chelated waste to Richland (NRC90). Three radionuclides made up nearly 95 percent of the total chelated activity. These were Co-60 (45.7%), Fe-55 (38.2%), and Cs-137 (11.4 %) (NRC90). The remaining radionuclides include H-3, C-14, Mn-54, Ni-63, Sr-90, Tc-99, I-129, and Cs-134 (NRC90).

5.3 Detailed Characterization of Waste Properties

The detailed characterization of industrial low-level waste is based on information obtained from the National Low-Level Waste Management Program database, known as "MIMS" (EGG90). Low-level waste data were made available in electronic files from EG&G Idaho, Inc. (MUN90, MUN91) for all three disposal sites. The supplied electronic files contain LLW data at the shipment level for five years, from 1986 to 1990. However, data at the container level were available only for Beatty and Richland from 1988 to 1990.

Table 5-2 Industrial Waste Volumes and Activity Levels by Compact Regions and States - Aggregate Practices from 1986 to 1990[(a)]

	Volume		Activity	
Compact/State	Vol. (m^3)	Percent	Act. (Ci)	Percent
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	1[illegible]	<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,[illegible]	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. All entries are rounded off and percentages may not add up to 100%. Puerto Rico did not ship 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.

Table 5-3 Yearly Activity and Waste Volumes Generated by the Industrial Sector[a]

Year		Industrial	Total (Excluding Utilities)
1986	Volume (m^3)	1.80E+4	2.18E+4
	Percent	84.4	100
	Activity (Ci)	5.82E+4	6.32E+4
	Percent	92.1	100
1987	Volume (m^3)	1.89E+4	2.48E+4
	Percent	76.2	100
	Activity (Ci)	4.25E+4	4.98E+4
	Percent	85.3	100
1988	Volume (m^3)	1.32E+4	1.75E+4
	Percent	75.4	100
	Activity (Ci)	3.44E+4	4.62E+4
	Percent	74.4	100
1989	Volume (m^3)	1.61E+4	2.21E+4
	Percent	72.8	100
	Activity (Ci)	1.27E+5	1.41E+5
	Percent	89.8	100
1990	Volume (m^3)	1.01E+4	1.42E+4
	Percent	71.3	100
	Activity (Ci)	1.03E+5	1.14E+5
	Percent	90.1	100
TOTAL	Volume (m^3)	7.63E+4	1.00E+5
	Percent	76.3	100
	Activity (Ci)	3.65E+5	4.18E+5
	Percent	87.3	100

(a) Data extracted from NUREG-1418 (NRC90), 1989 State-by-State Assessment (EGG90), and on-line MIMS service. 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.

In both cases, the 1990 data reflect information posted by the end of November 1990. This information was also supplemented by data obtained through direct access with the on-line MIMS system.

A description of the program, along with a discussion of data manipulation and selection and program validation, is provided in Section 2 and in Appendix B. Sample copies of shipping manifest forms can be found in Appendix A.

5.3.1 Waste Characterization - Container Level

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

- 43 shipping manifests
- 2,535 container records
- 796 cubic meters of waste
- 529,800 kg of waste, 0.66 g/cm^3 average density
- 4,240 Ci of total activity, 5.33 Ci/m^3

Table 5-3 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered and Class A, B, and C, generated from 1988 to 1990 was 39,400 cubic meters and 264,400 Ci, respectively. Accordingly, this search represents about two percent of the volume and 1.6 percent of the total activity of waste shipped by industrial waste generators. Unlike the other categories of waste generators, the percent of the total waste volume and total activity captured by the search is almost the same. This would indicate that the total activity associated with Class B and C is a small portion of the total activity of the waste shipped for disposal. In addition, the average gross radionuclide concentration is about the same as that in industrial waste from 1988 to 1990; i.e., 5.3 Ci/m^3 versus 6.7 Ci/m^3.

Appendix C reveals that the container-level data for industrial facilities are from virtually all regions of the United States, which would indicate that the data are representative of all Class A containers. However, as will be demonstrated in the subsequent sections addressing shipment-level data, these data are not representative and appear to have captured the very upper end of the radionuclide concentration distribution.

Exhibit 5-1 presents the concentration distributions of the principal radionuclides and some of the less abundant ones, such as Pu-241 and U-238, contained in the 2,535 containers captured by the sort. The following summarizes the results:

Radionuclide	Class A Limits (Ci/m^3)	Activity Shipped (Ci)	Concentration (Ci/m^3) Median	Average	1%ile	10%ile	90%ile	99%ile
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					
U-238	**	6.1E-03	5.4E-04	5.59E-04	4.7E-06	4.71E-06	8.05E-04	7.5E-03
	Total	3.60E+03						

* For activated metals, the limit is 8.0 Ci/m^3.
** There are no corresponding limits in 10 CFR 61.55.
*** Units are in nCi/g.

The sort captured 102 radionuclides. However, the radionuclides listed above account for 3,602 of the 4,240 Curies (or 85%) captured by the sort. Few generalizations can be made regarding the distributions of radionuclide concentrations, except that for a few radionuclides, the concentrations span several orders of magnitude, with no apparent pattern to the distributions. The 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, corresponding to a 55-gallon drum concentration of 4.7E-06 Ci/m^3.

A more detailed characterization of radionuclide concentration distributions, sorted at the container level and by waste stream, is provided in Appendix C. Each table presents the following information: waste class, waste stream and stabilization agent (if cited by the generator), number of shipping and container records captured by the sort, total waste volume and mass, and average waste density.

In all cases, the analyses are based on information contained in the Beatty and Richland database from 1/1/88 to 11/30/90. The data describe the properties of waste shipped directly (i.e., non-brokered) by the generator to a disposal site. Waste shipped by brokers are not included here (see Section 8.0 for details) as they do not contain information at the container level that can be assigned to a specific category of waste generator.

EXHIBIT 5-1

INDUSTRIAL WASTE - CONTAINER LEVEL ANALYSIS

Number of shipping records captured:	43
Number of container records captured:	2,535
Number of isotope records captured:	9,655
Total activity of containers (Ci):	4.24E+03
Total volume of containers (m^3):	7.96E+02
Total weight of containers (kg):	5.29E+05
Total density (g/cm^3):	6.66E-01
Total concentration (Ci/m^3):	5.33E+00
Total concentration (pCi/g):	8.00E+06

Exhibit 5-1 (Continued)

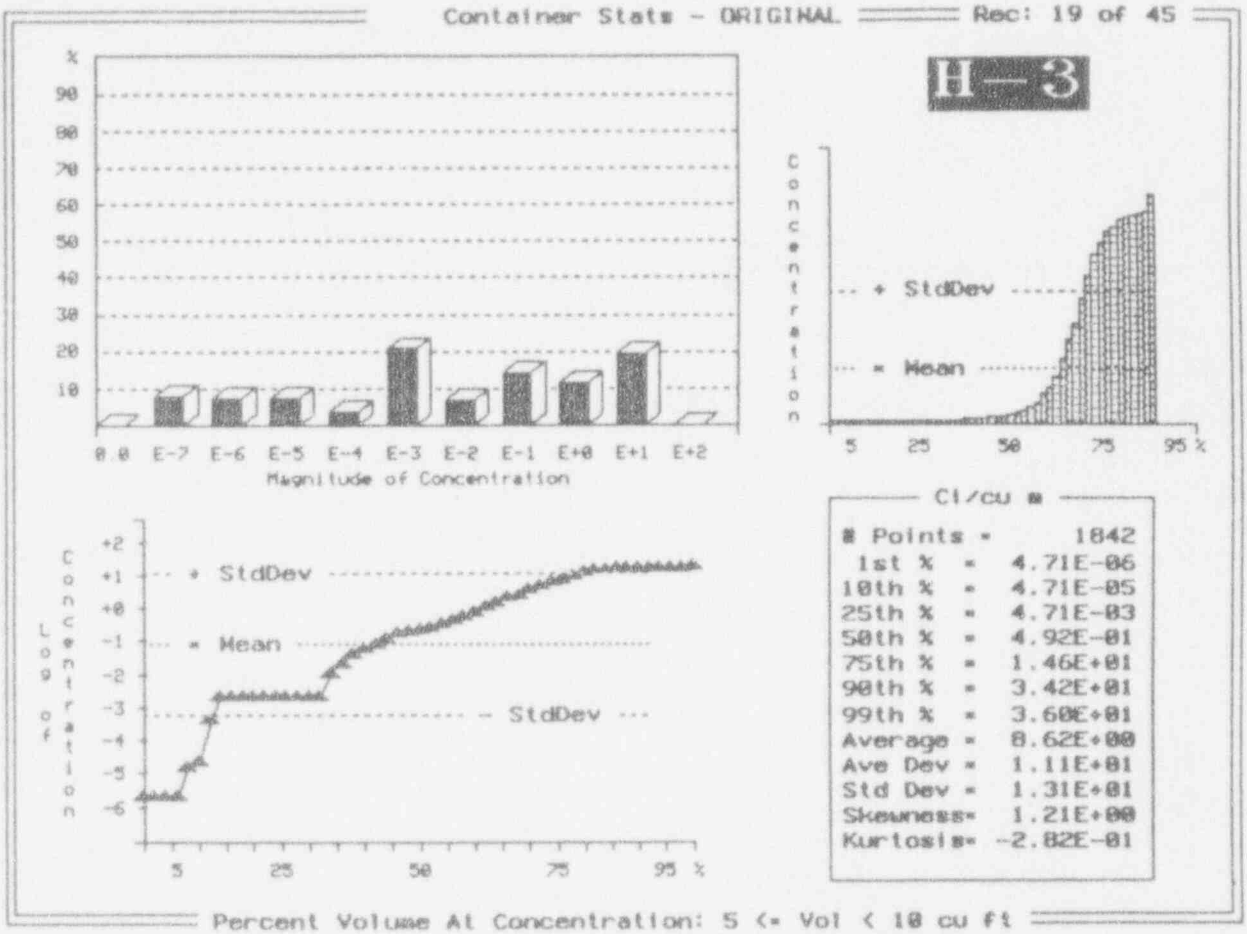
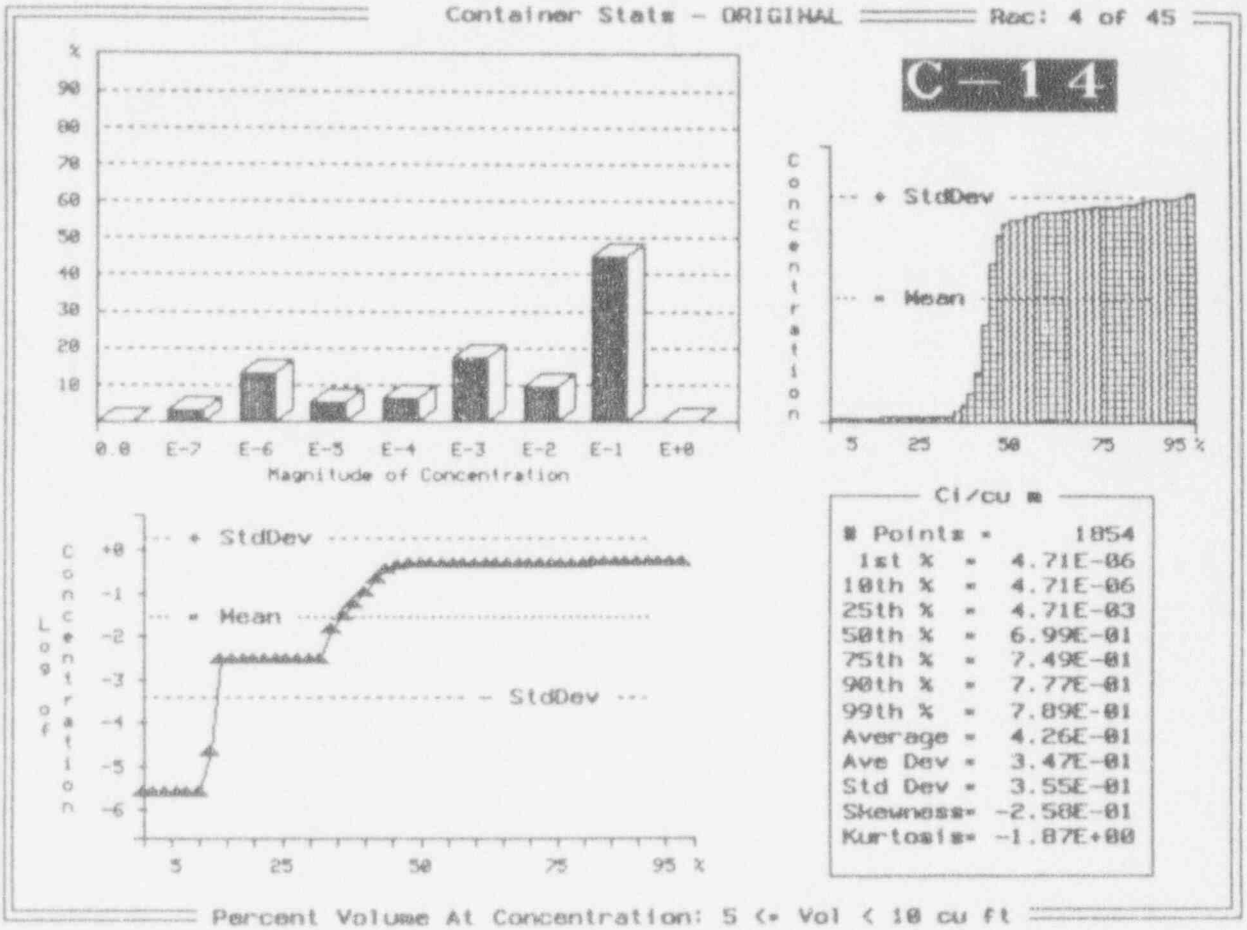


Exhibit 5-1 (Continued)



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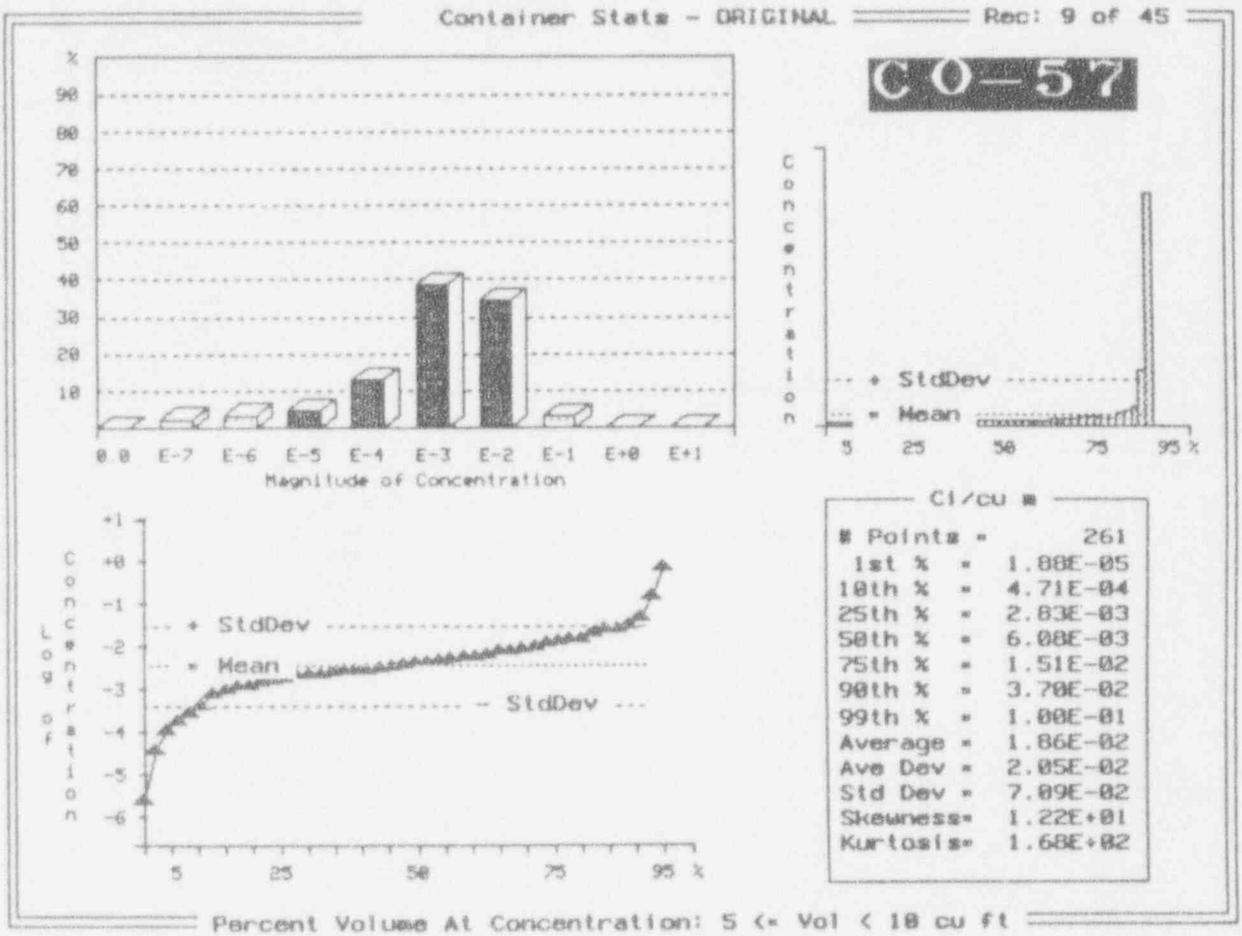

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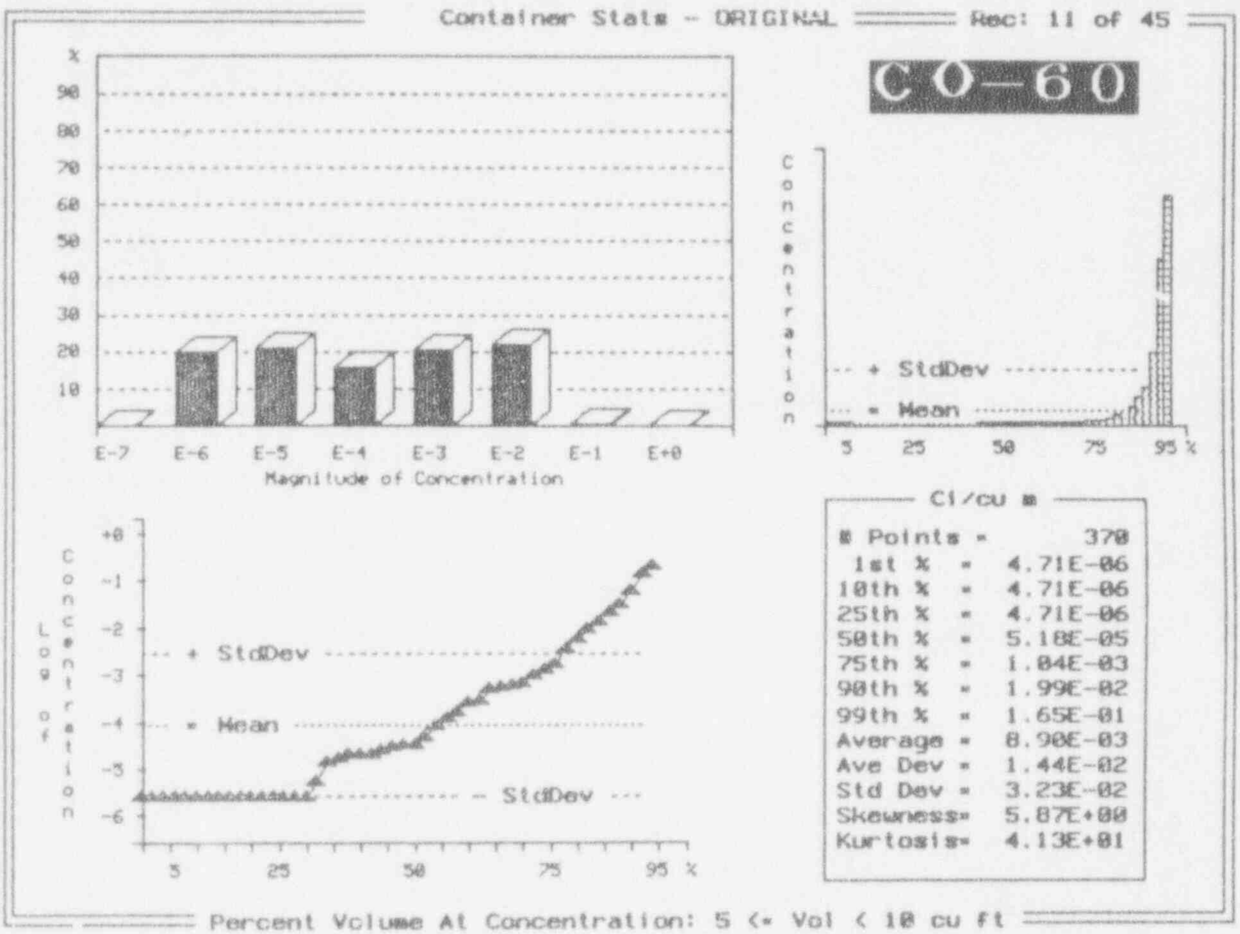
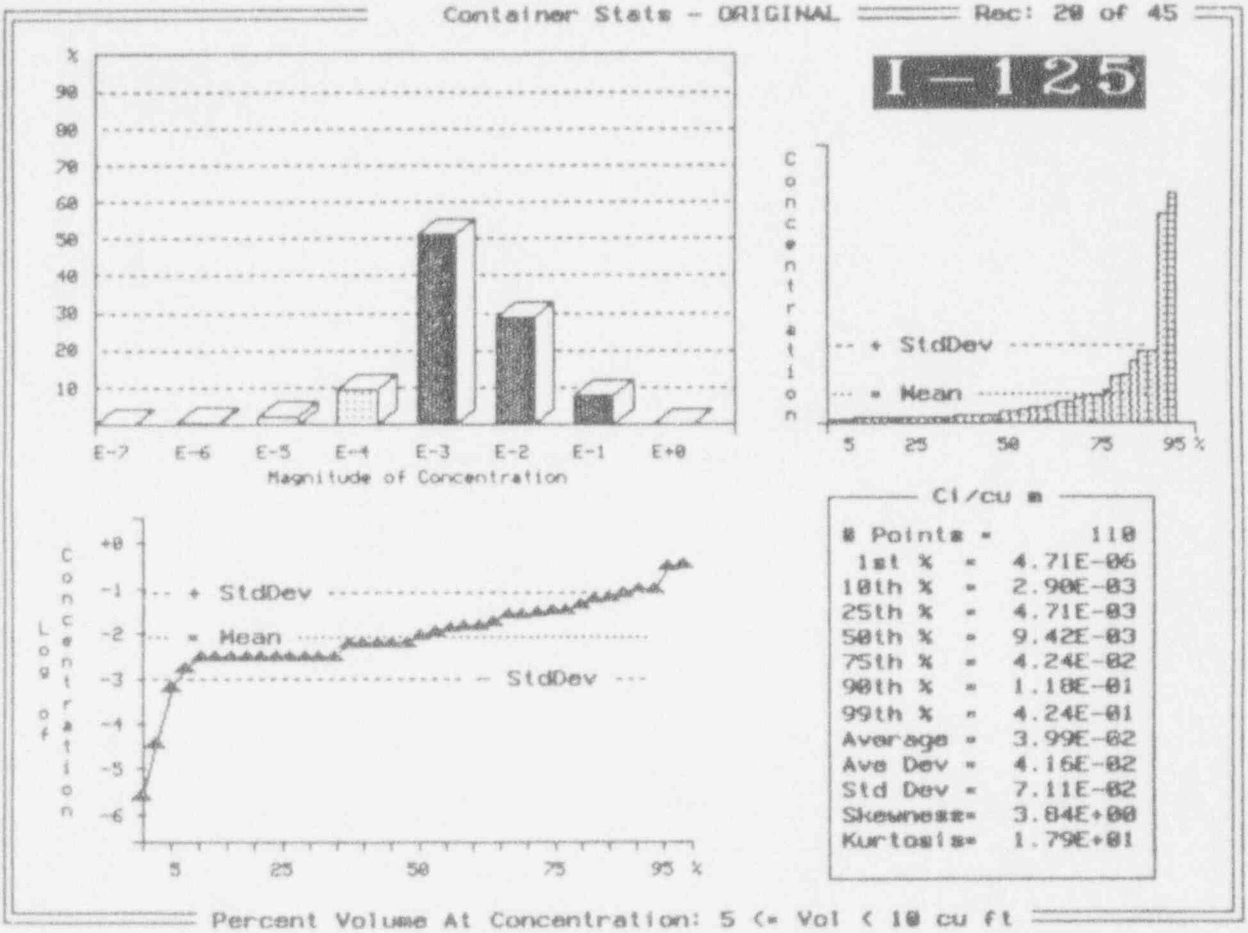


Exhibit 5-1 (Continued)



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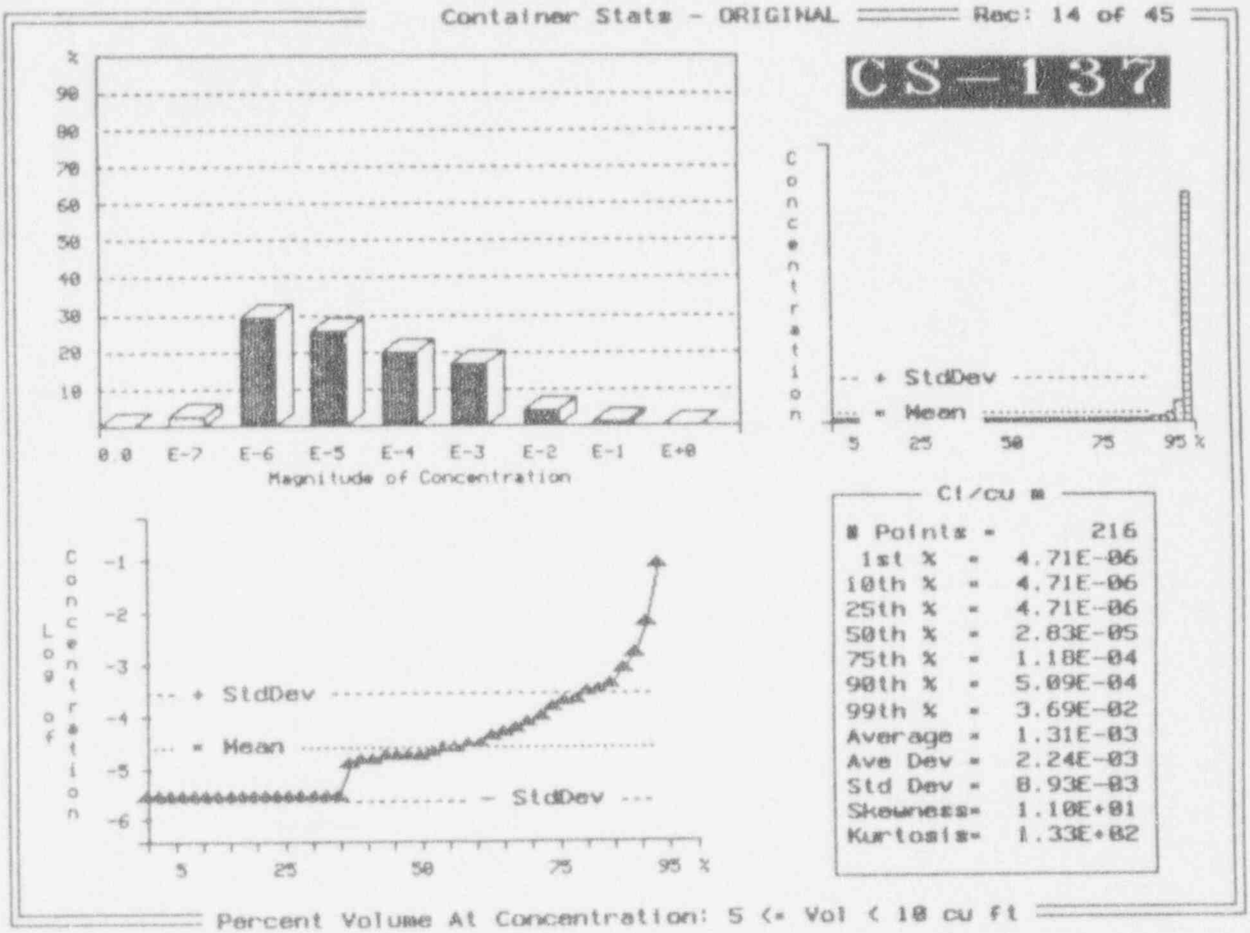


Exhibit 5-1 (Continued)

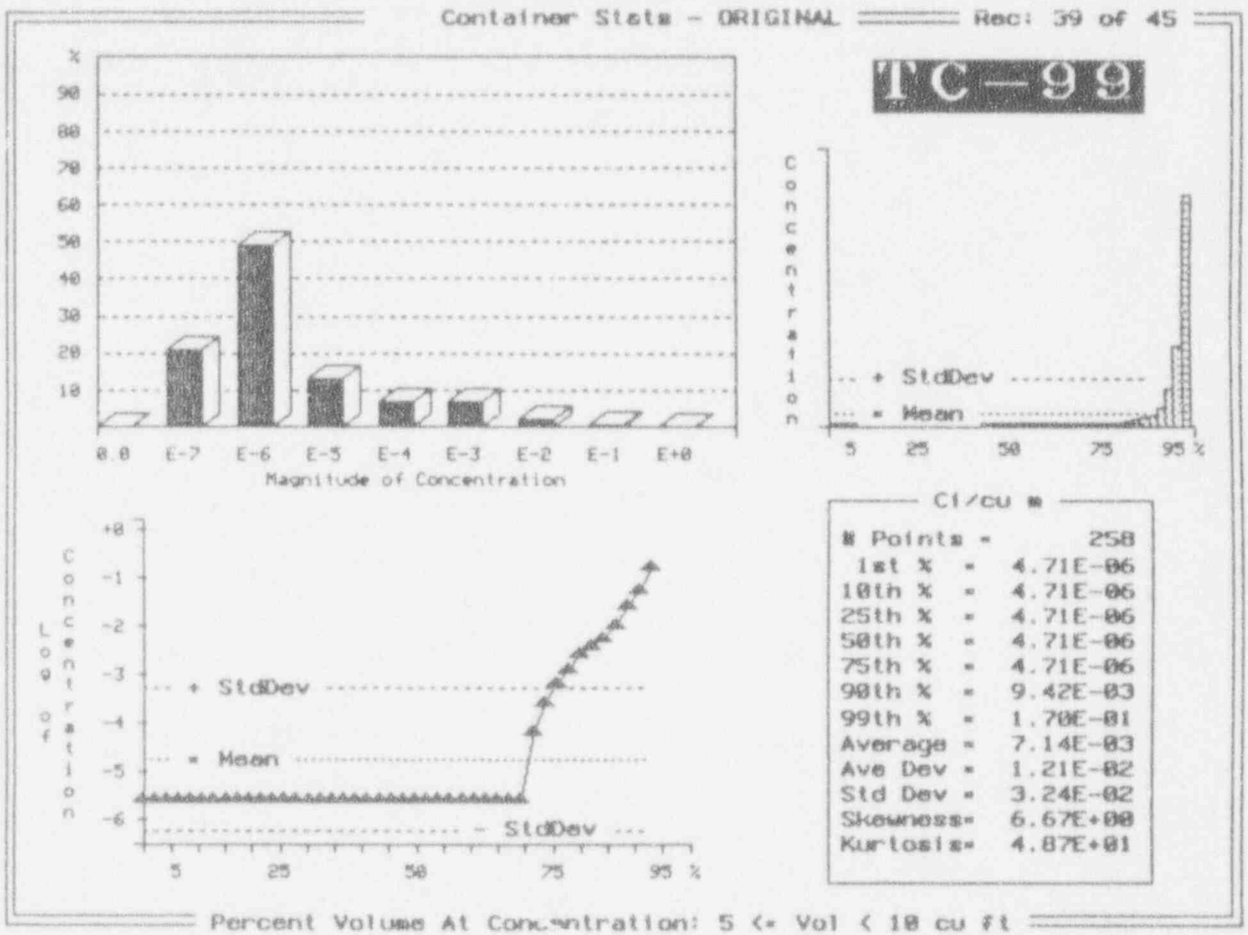
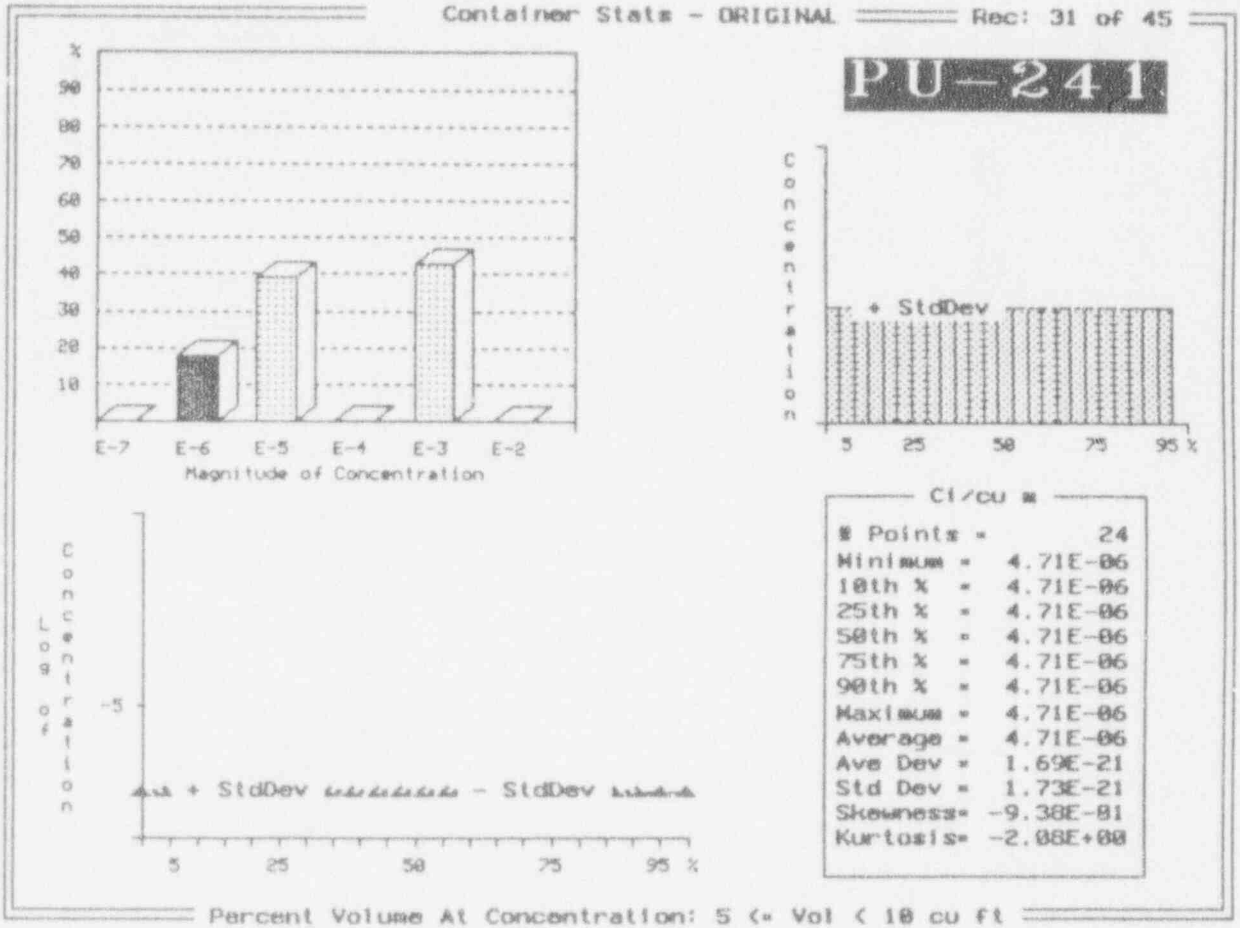


Exhibit 5-1 (Continued)



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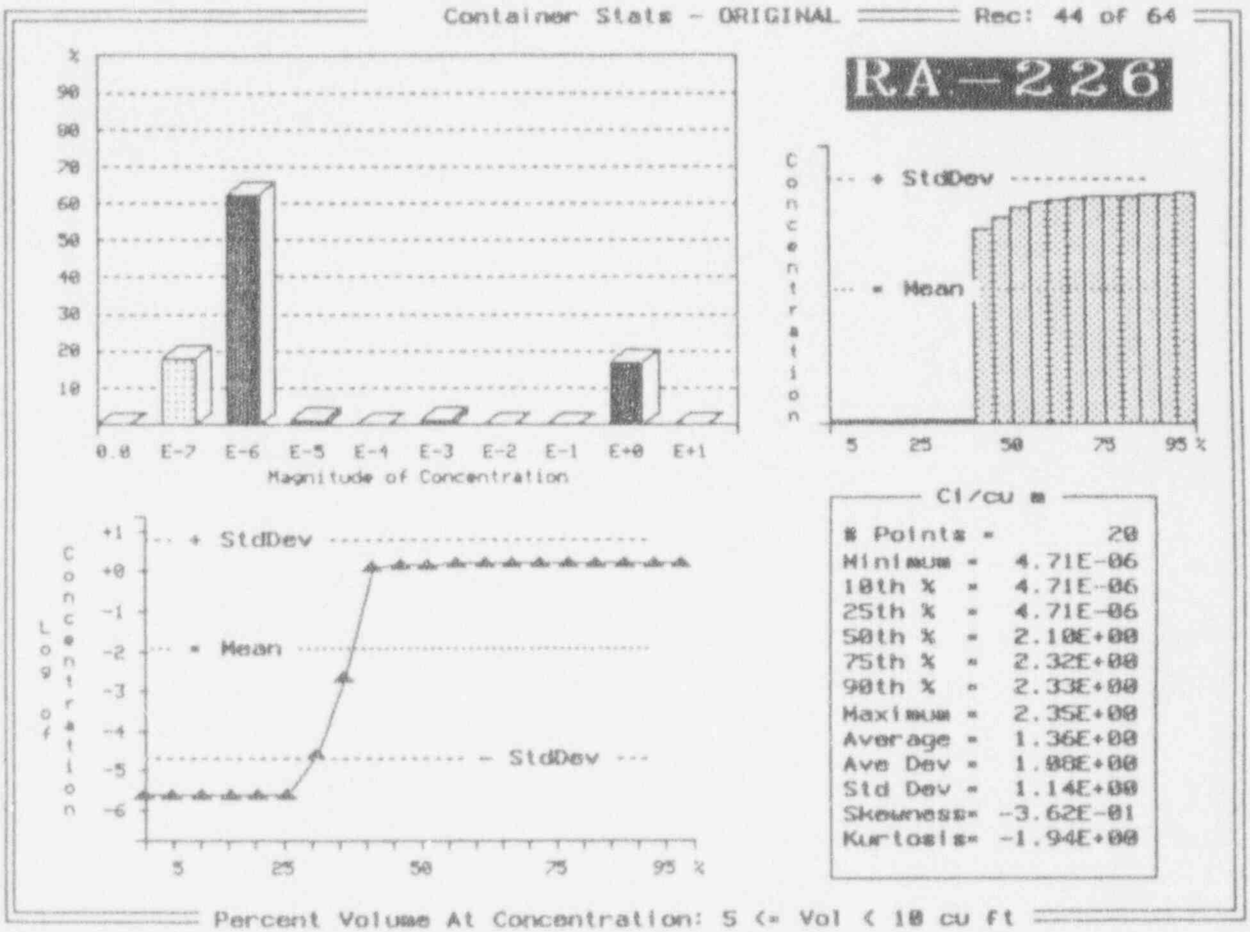
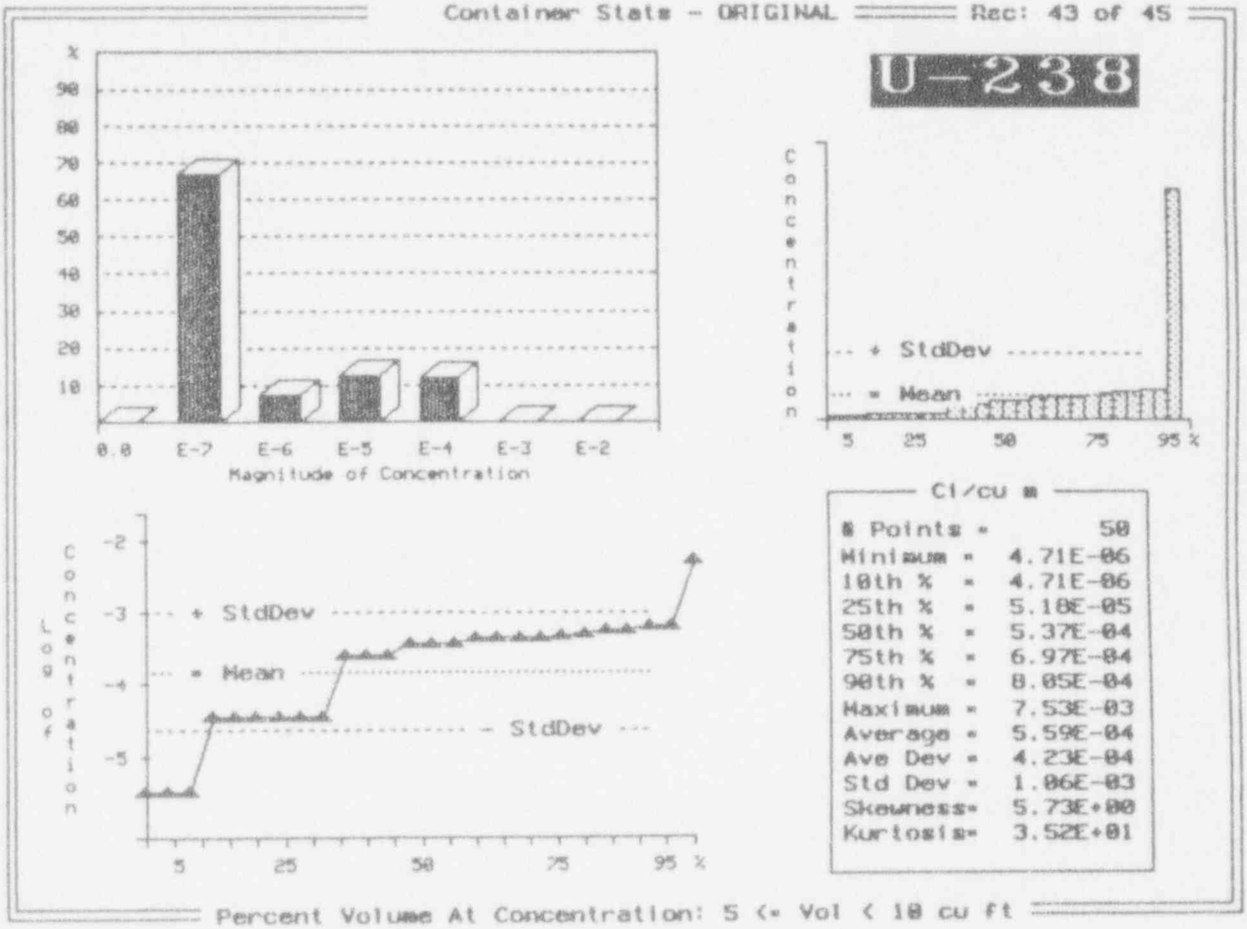


Exhibit 5-1 (Continued)



A review of the results presented in Appendix C indicates that, when compared to the selected list of radionuclides shown in Table 5-1, more nuclides are routinely cited by waste generators. These radionuclides include H-3, C-14, Na-22, P-32, P-33, S-35, Cl-36, Ca-45, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ge-68, Ge-67, Ga-68, Se-75, Rb-86, Sr-85, Kr-85, Y-88, Y-90, Sr-90, Tc-99, Ru-103, Ru-106, Cd-109, Ag-110m, Sn-113, In-114m, Sn-113, I-125, I-129, Ba-133, Cs-134, Cs-137, Ce-139, Ce-141, Gd-153, Tl-201, Hg-203, Po-210, Ra-226, Th-232, U-238, and Am-241.

This listing comprises the majority of the radionuclides being reported by industrial generators and over 99 percent of activity shipped for disposal. Radionuclides that are infrequently reported or that make up relatively lower waste activity levels include, for example, uranium and plutonium and their isotopes, natural uranium and thorium, depleted uranium, antimony, europium, platinum, bismuth, lead, tantalum, zirconium, etc.

The container-level sort captured the following waste streams, which is consistent with the waste streams reported in the literature:

- dry solids,
- sorbed and solidified aqueous liquids,
- non-compacted and compacted dry active waste,
- aqueous liquids in vials and sorbents,
- solidified oils and resins,
- dewatered resins,
- animal carcasses and biological waste,
- cartridge filter media,
- dewatered resins, spent resins,
- evaporator bottoms, and
- other unspecified waste materials.

In addition, industrial generators may infrequently generate waste associated with facility decontamination and decommissioning or refurbishment. Waste generated during such activities may include dry solids, compacted dry active, and non-compacted dry active waste. However, it is not possible to extract from the database the volumes and characteristics of such waste.

The tables in Appendix C, which present data sorts by Compact regions and waste streams, are based on varying numbers of shipments and containers, from a single shipping and container record to as many as 62 shipping and 2,171 container records.

Higher numbers of shipping and container records provide a better characterization of waste radionuclide distributions.

Using data obtained from Appendix C, Table 5-4 presents a summary comparison of selected radionuclide concentration distributions for specific waste streams and for different regions of the United States. The data in Table 5-4 and Appendix C reveal that radionuclide concentrations routinely vary by several orders of magnitude among regions and waste streams.

The data in Appendix C reveal that mass concentrations vary from about 0.1 pCi/g to 10^9 pCi/g. Except for 17 radionuclides, most concentrations fall within a narrower range, typically from 10^2 to 10^5 pCi/g. Higher concentrations tend to range from 10^6 to 10^8 pCi/g for such radionuclides as H-3, C-14, P-32, S-35, Cl-36, Ca-45, Mn-54, Fe-55, Co-60, Ni-63, Zn-65, Cd-109, I-125, Cs-137, Gd-153, Ra-226, and U-238.

Appendix D presents information similar to that provided in Appendix C, except sorted by waste stream only (i.e., the data were not sorted by Compact or State). Each sort provided in Appendix D includes a summary sheet, which offers additional information, including the total number of shipping and container records captured by the sort, weight of waste shipments, and total and fractional waste volumes and activity levels.

5.3.2 Waste Characterization - Shipment Level

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

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

On inspection, Table 5-3 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered, generated from 1986 to 1990 was 76,300 cubic meters and 365,000 Ci, respectively. Accordingly, this search represents over 72 percent of the volume (the balance was shipped by brokers, and a small portion is Class B and C waste) and nearly 29 percent of the activity of the waste shipped for disposal. 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.

Table 5-4

Comparison of Selected Radionuclide Concentration Distributions in Container-Level Industrial Waste

	Radionuclide (Ci/m³) - Percentile											
	C-14			H-3			Ra-226			Co-60		
	1	50	99	1	50	99	1	50	99	1	50	99
<u>Aggregate</u>	4.7E-6	7.0E-1	7.9E-1	4.7E-6	4.9E-1	3.6E+1	4.7E-6	2.1E+00	2.4E+00	4.7E-6	5.2E-5	1.7E-1
<u>Northwest</u>												
Dry Solid	Only One Record			4.7E-6	4.7E-3	1.5E-1	1.4E-5	3.6E-4	8.9E-4	4.7E-6	2.4E-5	4.6E-3
Absorbed Aqueous Liquids	2.6E-5	2.6E-5	4.4E-5	4.7E-6	1.9E-5	1.4E-3	Less than 4.7E-6			4.7E-6	4.7E-6	2.8E-5
Non-Compacted DAW										4.7E-6	1.4E-4	6.1E-1
Unspecified							9.9E-5	3.3E-4	7.5E-4			
Animal Carcasses				1.9E-1	1.9E-1	1.9E-1						
Solidified Liquids										4.7E-6	4.7E-6	4.3E-2
<u>Rocky Mountain</u>												
Dry Solid										4.7E-6	8.1E-4	2.1E-3
Non-Compacted DAW										4.7E-6	2.6E-4	8.5E-3
Unsp. Biological										1.3E-3	1.3E-3	1.3E-3
<u>Central</u>												
Dry Solid							1.8E-3	1.8E-3	2.2E-3			
<u>Midwest</u>												
Dry Solid	4.7E-6	7.6E-3	9.4E-2	4.1E-3	4.4E-3	4.4E-3	4.7E-6	4.7E-6	3.8E-3			
<u>Southeast</u>												
Non-Compacted DAW							8.7E-4	8.8E-4	1.8E-3			

Table 5-4 (continued)

Comparison of Selected Radionuclide Concentration Distributions in Container-Level Industrial Waste

	Radionuclide (Ci/m^3) - Percentile											
	C-14			H-3			Ra-226			Co-60		
	1	50	99	1	50	99	1	50	99	1	50	99
Aggregate	4.7E-6	7.0E-1	7.9E-1	4.7E-6	4.9E-1	3.6E+1	4.7E-6	2.1E+00	2.4E+00	4.7E-6	5.2E-5	1.7E-1
Northeast												
Dry Solid							1.8E-3	1.8E-3	2.2E-3			
Solidified Oils										4.7E-5	2.1E-4	1.6E-3
Appalachian												
Non-Compacted DAW	9.4E-6	2.8E-5	1.3E-4	4.7E-6	4.7E-6	1.9E-5	4.7E-6	4.7E-6	3.8E-3	8.2E-2	2.0E-2	9.9E-2
Solidified Resins	4.7E-5	5.2E-5	8.5E-5							3.8E-2	4.0E-2	6.4E-2
Dry Solid				4.7E-1	4.8E-5	5.7E-5				4.7E-6	3.8E-5	2.9E-4
Solidified Liquids	9.7E-5	1.2E-4	2.7E-4	1.1E-5	1.3E-5	4.8E-5				8.2E-3	2.6E-2	3.4E-2
Southwest												
Dry Solid	4.7E-3	4.7E-3	4.7E-3	4.7E-3	4.7E-3	2.4E-2				4.7E-6	1.3E-2	9.5E-1
Compacted DAW	3.5E-7	4.0E-6	2.3E-4	3.5E-7	4.1E-7	6.5E-6				4.4E-2	4.4E-2	2.6E-1
Non-Compacted DAW										4.7E-6	2.4E-5	4.8E-1
Solidified Liquids				1.4E+2	4.0E+3	4.5E+3				1.9E-3	2.1E-2	8.1E-2
Sorbed Aq. Liquid	4.7E-3	4.7E-2	7.5E-1	4.7E-3	4.7E-2	2.4E+1				5.2E-3	2.9E-2	3.2E-1
Cartridge Type Filter Media										7.6E-4	1.1E-3	3.7E-3
Solidified Oil										5.2E-3	1.3E-2	1.2E-1
Dewatered Resins										5.2E-3	1.6E-2	1.3E+1
Resins										1.3E+0	1.3E+0	7.1E+0

Table 5-4 (continued)

Comparison of Selected Radionuclide Concentration Distributions in Container-Level Industrial Waste

	Radionuclide (Ci/m^3) - Percentile											
	C-14			H-3			Ra-226			Co-60		
	1	50	99	1	50	99	1	50	99	1	50	99
<u>Aggregate</u>	4.7E-6	7.0E-1	7.9E-1	4.7E-6	4.9E-1	3.6E+1	4.7E-6	2.1E+00	2.4E+00	4.7E-6	5.2E-5	1.7E-1
<u>Massachusetts</u>												
Dry Solid	2.8E-5	7.4E-1	7.9E-1	4.7E-3	3.1E+0	3.6E+1				4.7E-6	4.7E-4	3.3E-1
Sorbed Aq. Liquid	4.7E-5	6.9E-1	7.9E-1	4.7E-5	8.9E+0	3.5E+1				4.2E-5	1.9E-3	9.1E-2
Solidified Liquids	4.2E-1	7.5E-1	7.9E-1	5.9E+0	3.3E+1	3.7E+1						
Solidified Oil	6.9E-1	7.4E-1	7.4E-1	6.2E+0	6.8E+0	1.0E+1						
<u>Texas</u>												
Compacted DAW	1.5E-4	7.2E-2	6.5E-1	3.3E-3	3.3E-1	3.5E+0				7.2E-4	7.2E-4	7.2E-4
Solidified Liquid	2.4E-4	2.4E-4	7.1E-4	2.4E-2	2.4E-2	4.3E-1						

A smaller percentage of the activity was captured by the sort relative to the volume because the data do not include Class B and C waste, which contain most of the radioactivity. The results also reveal that the average radionuclide concentrations at the container level are several times higher than at the shipment level, which raises some question as to the representativeness of the container-level data.

This inconsistency might be due to various causes, e.g., 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 raise the overall radionuclide concentration. The database does not provide the means to identify or trace the source of such discrepancies.

As noted earlier, the data at the shipment level cannot be sorted by waste stream. These data characterize aggregate radionuclide concentrations over the entire waste volume and mass of the shipment. The analyses represent aggregate practices based on direct shipments to all disposal sites and for all years (1/1/86 to 11/30/90).

Exhibit 5-2 presents the concentration distributions of the principal radionuclides contained in the shipments captured by the sort. The sorts are grouped into the following categories of shipment sizes:

- <10 cubic feet per shipment
- 10 to 50 cubic feet per shipment
- 50 to 100 cubic feet per shipment
- 100 to 500 cubic feet per shipment
- 500 to 1000 cubic feet per shipment

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides and shipment size categories containing the majority of the waste by volume and activity:

EXHIBIT 5-2

INDUSTRIAL WASTE - SHIPMENT LEVEL ANALYSIS

Number of shipping records captured:	5,029
Number records with container data:	632*
Number of manifests captured:	0
Number of container records captured:	29,943*
Number of isotope records captured.	16,658
Total activity of shipment (Ci):	1.05E+05
Total volume of shipments (m^3):	5.51E+04
Computed weight of shipments (kg):	5.64E+07
Total weight of containers (kg):	1.29E+07*
Nominal density (g/cm^3):	1.02E+00
Total density (g/cm^3):	1.18E+00*
Total concentration (Ci/m^3):	1.91E+00
Total concentration (pCi/g):	2.46E+06*

* For shipments with container data.

Exhibit 5-2 (Continued)

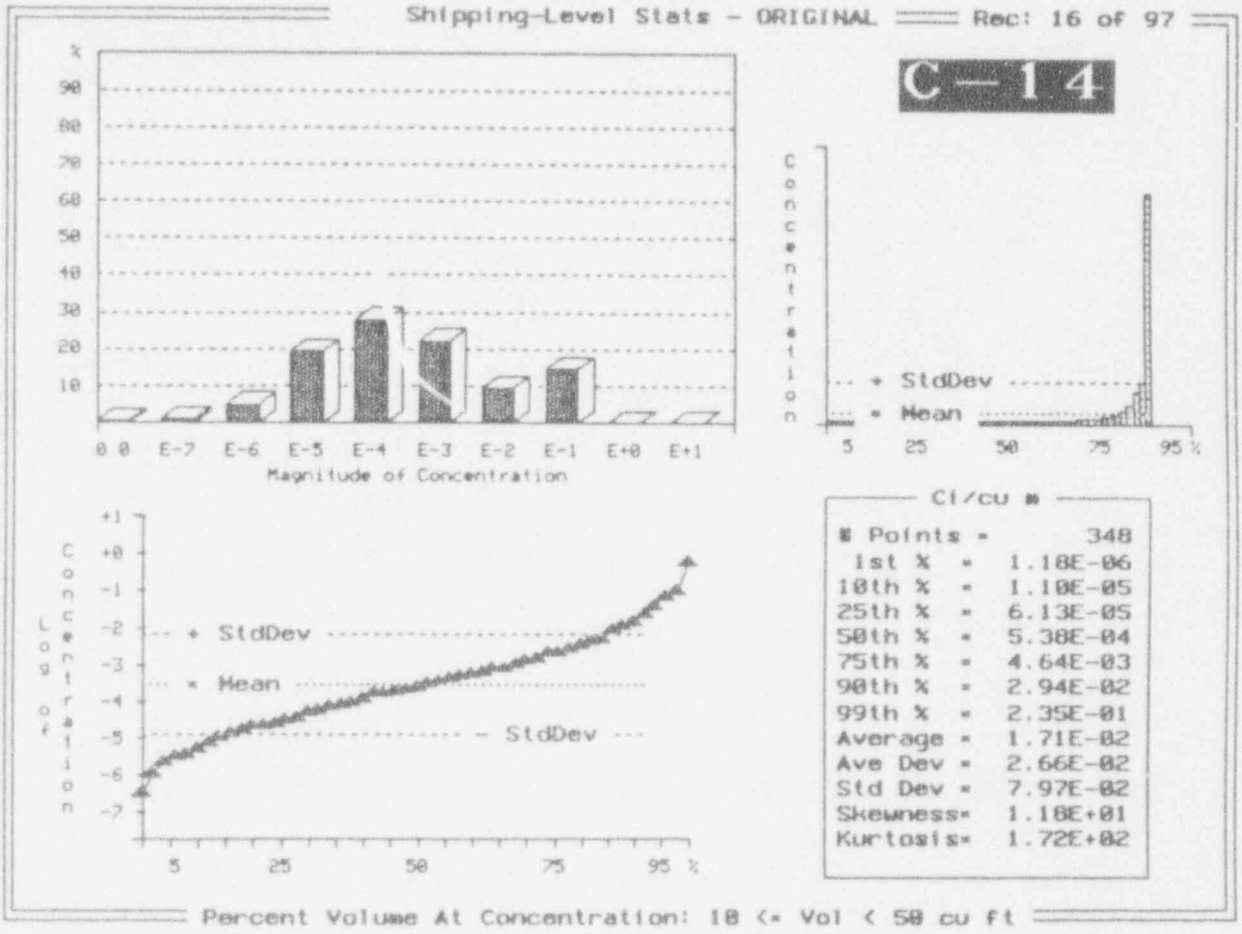
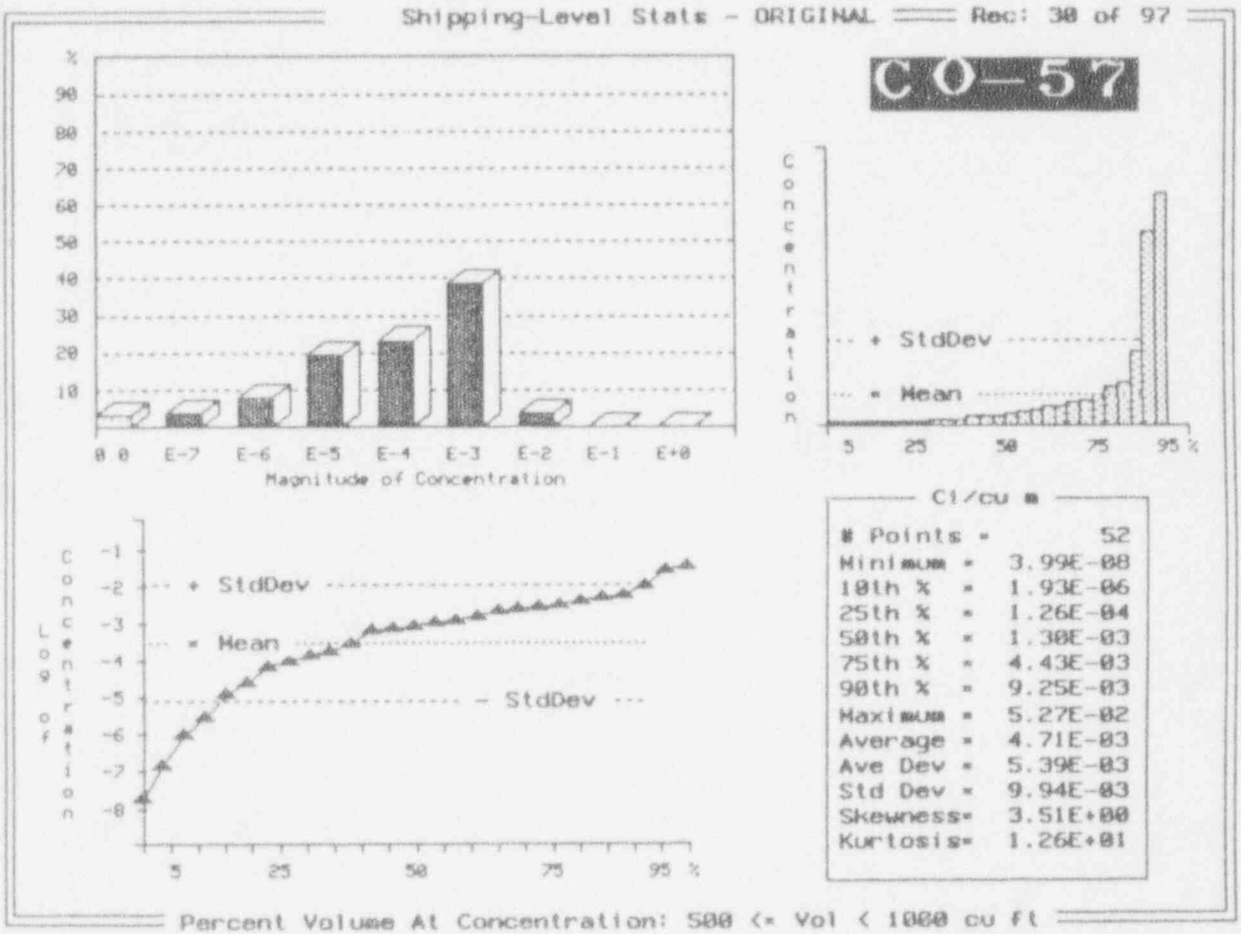


Exhibit 5-2 (Continued)



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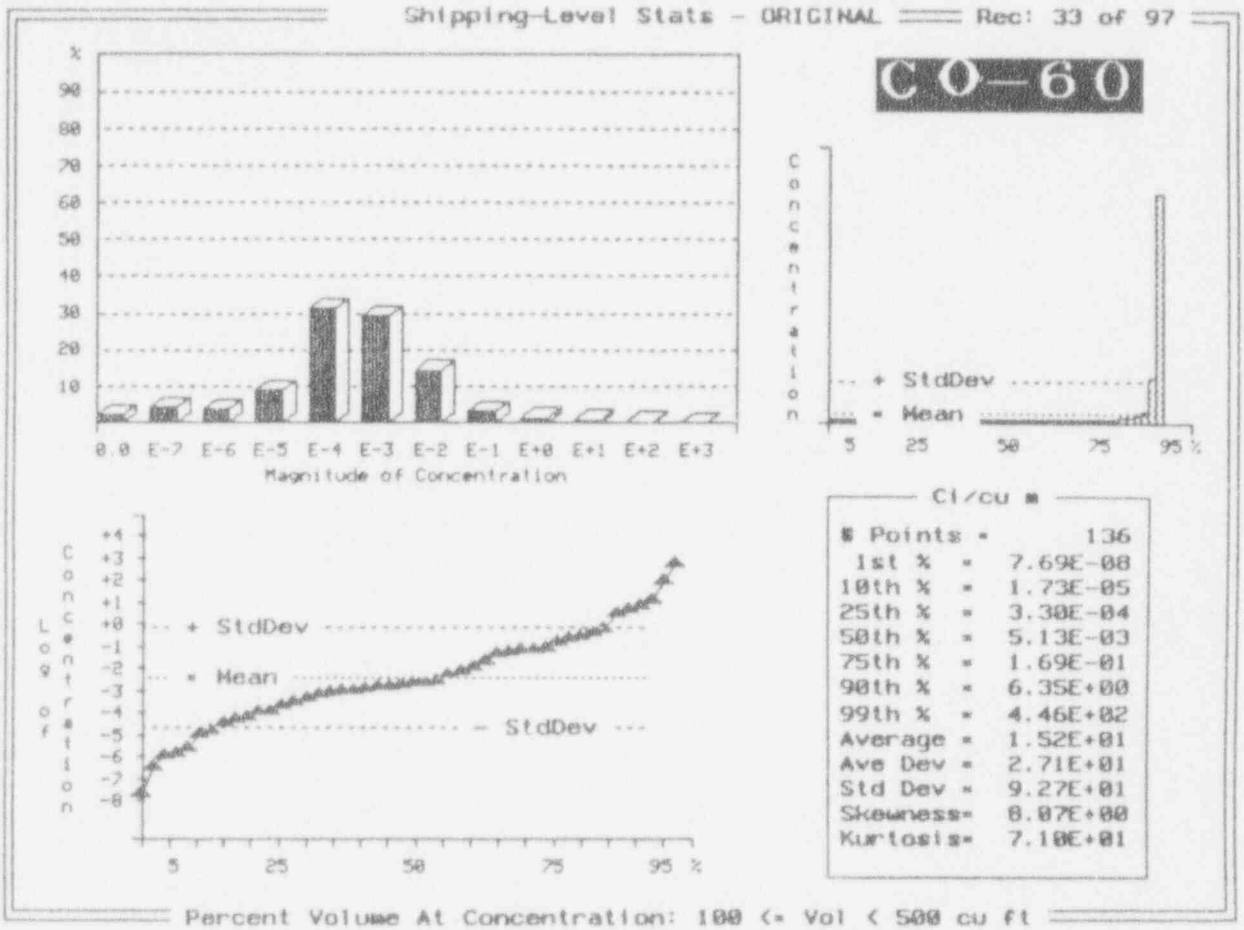

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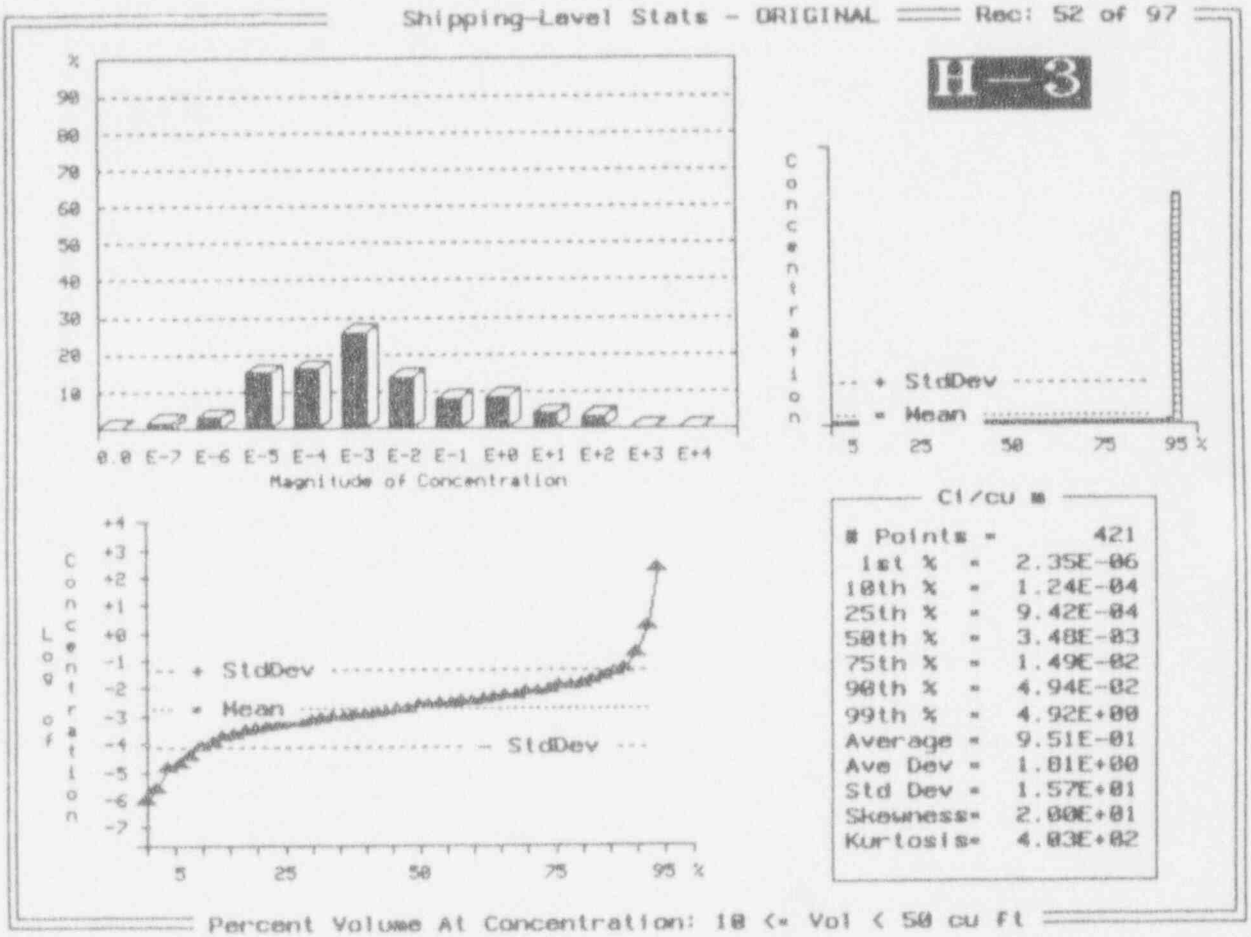

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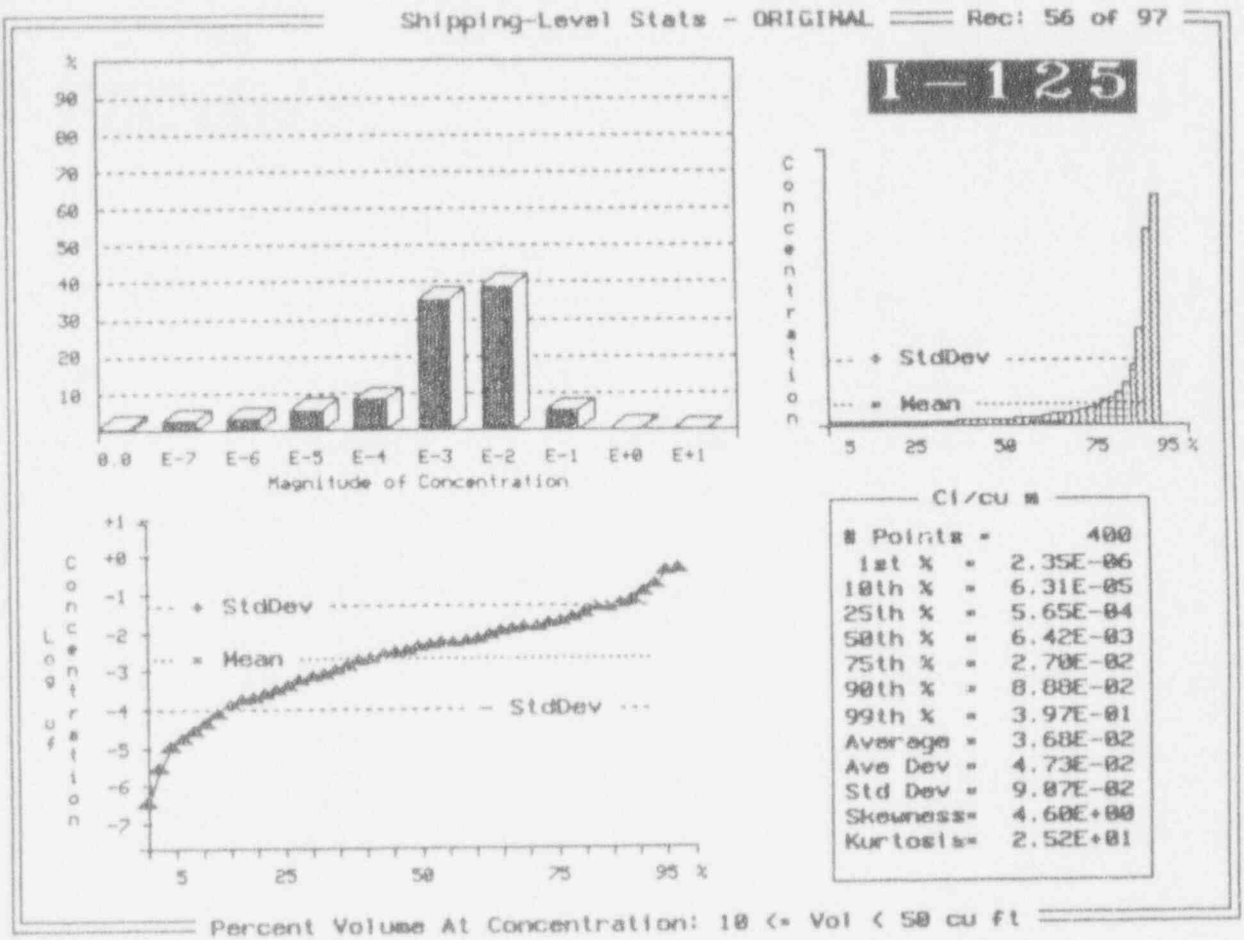

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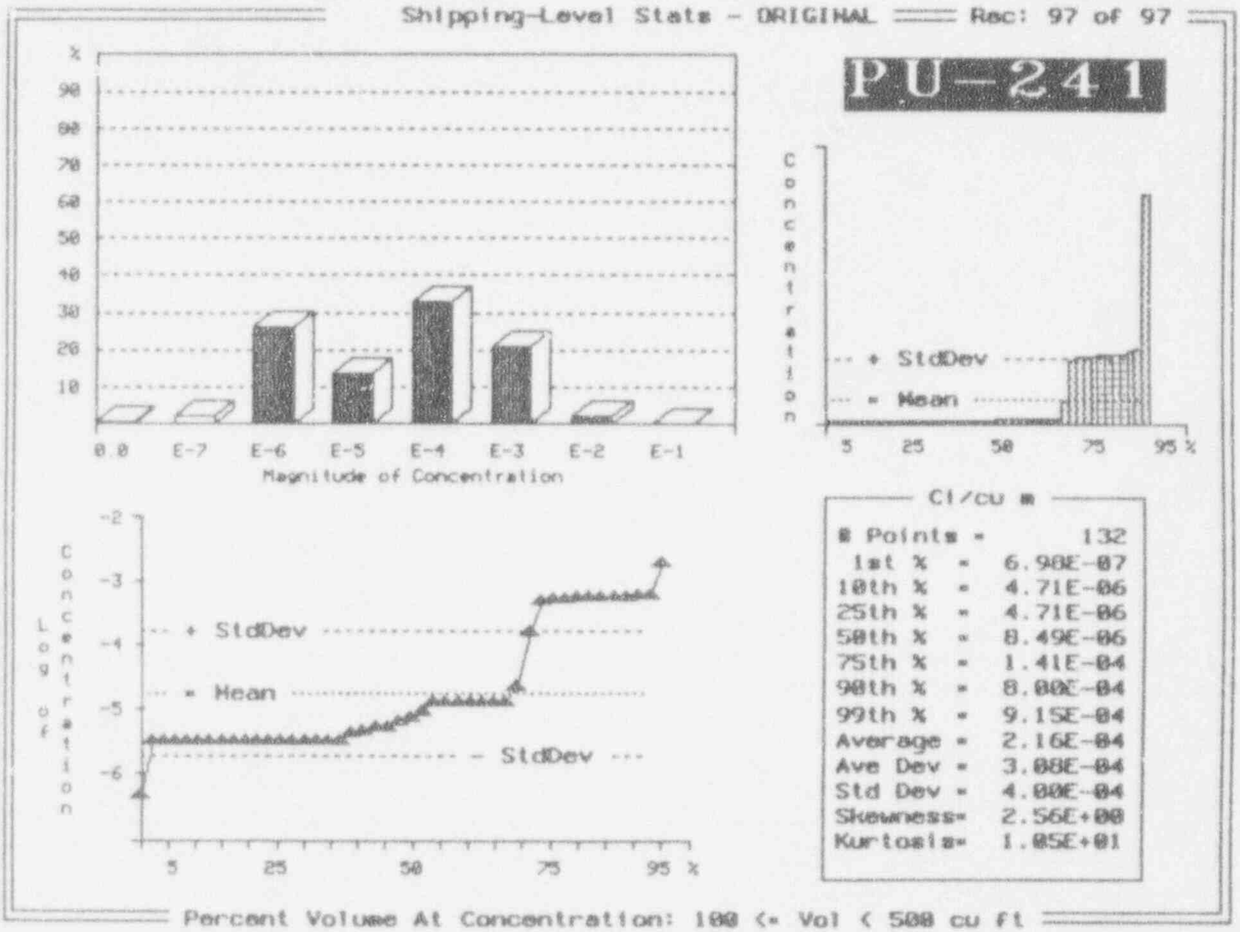

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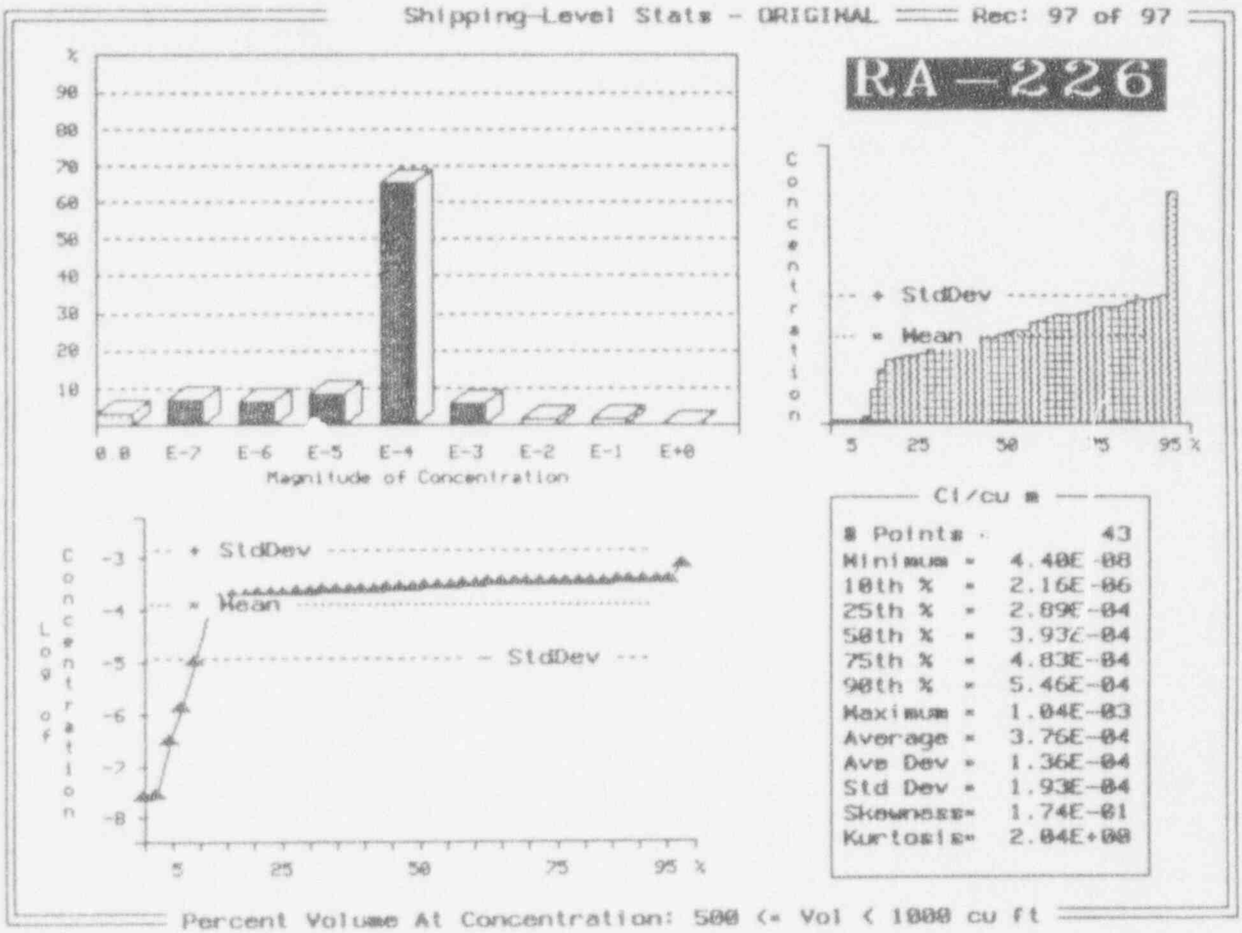

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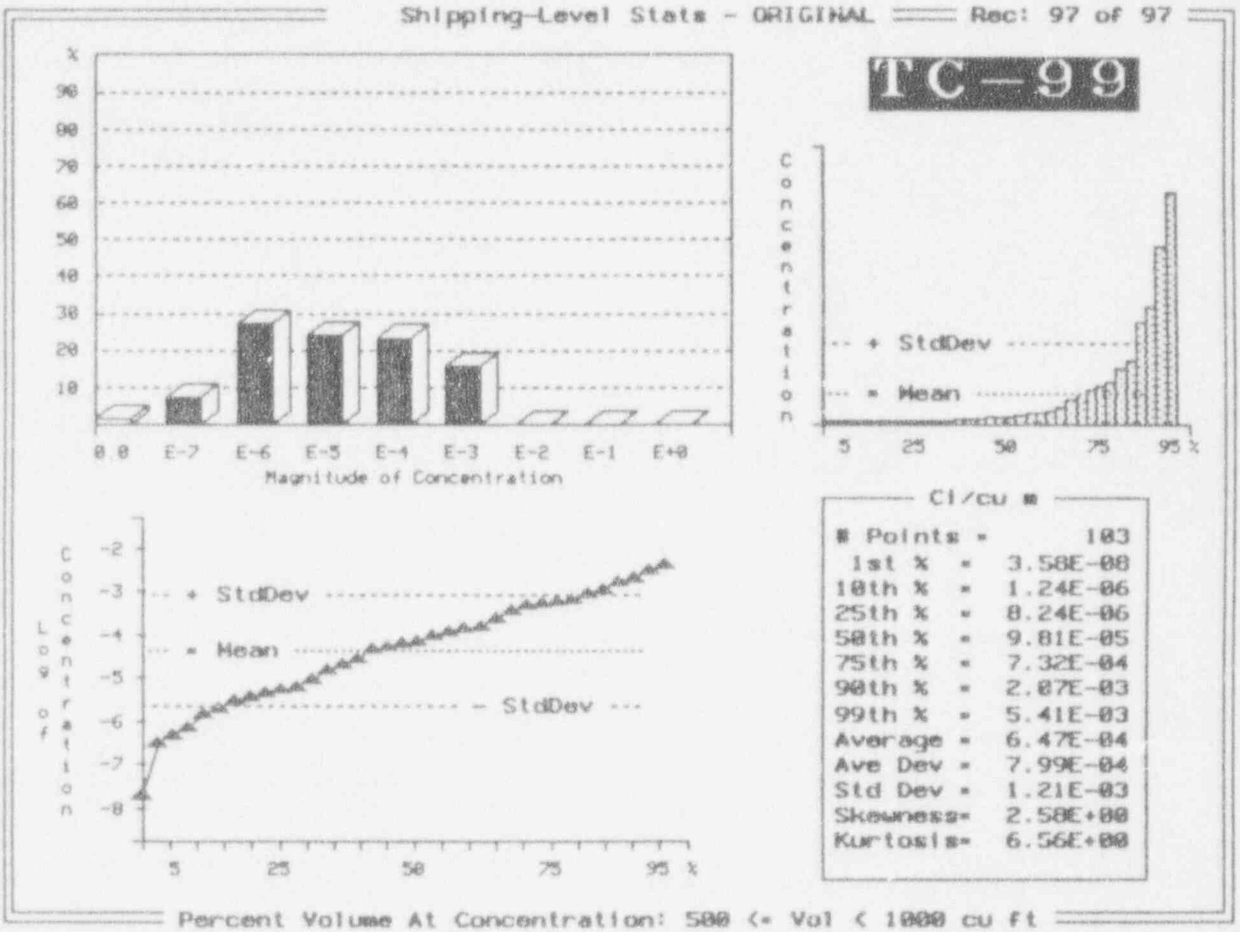

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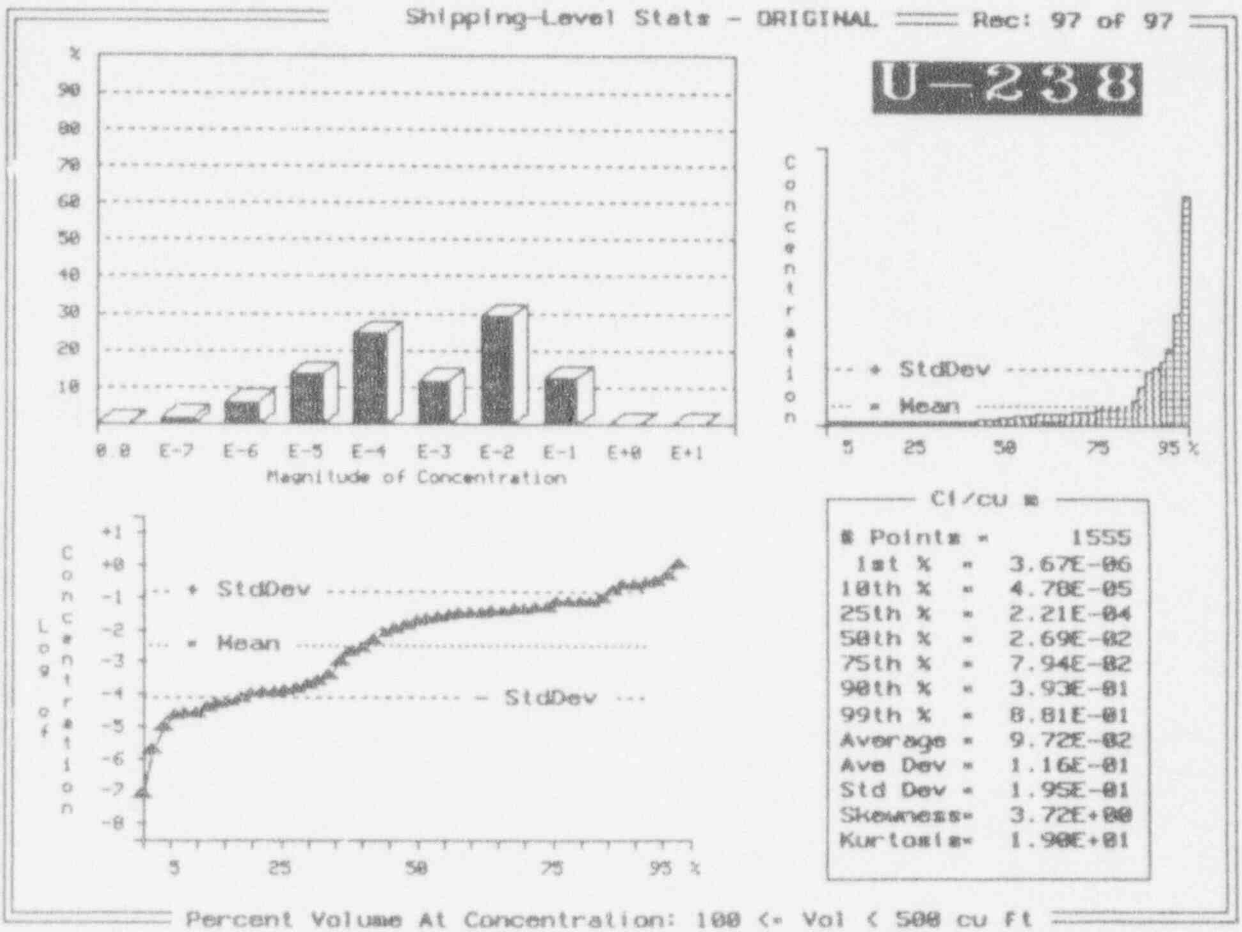

Radionuclide	10CFR61 Class A Limits	Total Activity Captured (Ci)	Concentration (Ci/m^3) Median	Average	1%ile or min.	10%ile	90%ile	99%ile or max.
C-14	0.8*	3.7E+02	5.4E-04	1.7E-02	1.2E-06	1.1E-05	2.9E-02	2.4E-01
Co-57	700	6.3E+00	1.3E-03	4.7E-03	4.0E-08	1.9E-06	9.3E-03	5.3E-02
Co-60	700	1.3E+04	5.1E-03	1.5E+01	7.7E-08	1.7E-05	6.4E+00	4.5E+02
H-3	40	8.5E+04	3.5E-03	9.5E-01	2.4E-06	1.2E-04	4.9E-02	4.9E+00
I-125	700	8.0E+01	6.4E-03	3.7E-02	2.4E-06	6.3E-05	8.9E-02	4.0E-01
Pu-241	350**	5.1E+00	8.5E-06	2.2E-04	7.0E-07	4.7E-06	8.0E-04	9.2E-04
Ra-226	***	7.9E+00	3.9E-04	3.8E-04	4.4E-08	2.2E-06	5.5E-04	1.0E-03
Tc-99	0.3	2.4E+00	9.8E-05	6.5E-04	3.6E-08	1.2E-06	2.1E-03	5.4E-03
U-238	***	1.4E+03	2.7E-02	9.7E-02	3.7E-06	4.8E-05	3.9E-01	8.8E-01
	Total	9.98E+04						

* In activated metals, the limit is 8.0 Ci/m^3.
** Units are in nCi/g.
*** There are no corresponding limits in 10 CFR 61.55.

The sort captured 171 radionuclides. However, the above-listed radionuclides account for 9.98E+04 of the 1.05E+5 Curies (or 95%) captured by the sort.

The shipment-level data were also sorted by Compact and State to determine the degree to which the radionuclide concentration distributions vary regionally. The results of these sorts are shown in Appendices E and F. Appendix E presents the results in tabular form, and Appendix F presents the results in the form of histograms and cumulative distribution curves. Radionuclide histograms and cumulative distributions are presented only for those nuclides that are consistently reported by waste generators. Appendix F also includes summary sheets that provide additional information, including the associated number of waste generators, total number of shipping records and containers captured in the analysis, weight of waste shipments, and total and fractional waste volumes and activity levels.

Table 5-5 summarizes the Appendix E data for selected nuclides. The results reveal little agreement between the container and shipment-level data. This is likely due to the very small fraction of the waste captured at the container level and the highly variable radionuclide concentrations. From Appendices E and F, the most often cited radionuclides include H-3, C-14, Na-22, P-32, P-33, S-35, Cl-36, Ca-45, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ge-68, Ge-67, Ga-68, Se-75, Rb-86, Sr-85, Kr-85, Y-88, Y-90, Sr-90, Tc-99, Ru-103, Ru-106, Cd-109, Ag-110m, Sn-113, In-114m, Sn-113, I-125, I-129, Ba-133, Cs-134, Cs-137, Ce-139, Ce-141, Gd-153, Tl-201, Hg-203, Po-210, Ra-226, Th-232, U-238, and Am-241.

Table 5-5

Comparison of the Selected Radionuclide Concentration Distributions at the Shipment Level for Industrial Waste Generators (1986 to 1990)

	Total Volume (m^3)	Volume Captured (m^3)	Radionuclide (Ci/m3) - Percentile: C-14			H-3			Ra-226			Co-60		
			1	50	99	1	50	99	1	50	99	1	50	99
Aggregate Container Level			4.7E-6	7.0E-1	7.9E-1	4.7E-6	4.9E-1	3.6E+1	4.7E-6	2.1E+0	2.4E+0	4.7E-6	5.2E-5	1.7E-1
Aggregate Shipment Level			1.2E-6	5.4E-4	2.4E-1	2.4E-6	3.5E-3	4.9E+0	4.4E-8	3.9E-4	1.0E-3	7.7E-8	5.1E-3	4.5E+2
Shipment Level By Region														
Northwest	12,800	1,364	1.6E-6	2.8E-5	7.9E-3	2.4E-6	5.4E-3	3.6E-1	2.3E-4	4.1E-4	1.0E-3	4.1E-6	2.8E-5	2.5E-2
Rocky Mountain	298	54.8							9.0E-6	3.9E-5	6.8E-5	9.9E-4	9.9E-4	9.9E-4
Central	5,980	5,584	2.6E-4	2.6E-4	2.6E-4	1.0E+0	1.0E+0	1.0E+0	5.5E-4	5.5E-4	5.5E-4	5.1E-8	5.1E-8	5.4E-4
Midwest	4,480	3,588	1.2E-5	1.5E-3	4.0E-2	2.1E-4	9.6E-3	3.3E+1	4.5E-6	8.3E-5	3.4E-3	3.8E-3	3.8E-3	2.0E-2
Central Midwest	2,700	602	3.0E-5	2.4E-3	1.2E-2	4.2E-6	6.3E-2	3.9E-1	1.4E-4	2.5E-3	9.4E-3	3.9E-6	9.6E-3	3.2E-2
Southeast	23,300	14,990	1.5E-4	1.8E-4	2.6E-1	9.0E-6	2.6E-3	5.3E+0	1.8E-5	6.0E-4	5.8E-3	8.7E-7	2.6E-3	1.8E-1
Northeast	3,770	1,396	1.9E-6	9.2E-4	4.1E-1	2.4E-6	3.1E-3	9.7E+0	2.6E-4	1.5E-3	1.4E-2	3.3E-6	3.6E-5	1.3E-2
Appalachian	4,990	3,032	9.4E-7	5.9E-4	1.3E-1	2.1E-7	1.0E-4	5.3E+0	4.8E-7	3.7E-4	1.8E-3	1.5E-6	4.7E-4	1.2E+0
Southwest	5,360	3,039	1.9E-6	1.2E-4	7.1E-3	6.3E-5	5.3E-3	1.7E-1	7.9E-7	5.0E-4	8.1E-2	8.7E-6	1.4E-1	3.1E+2
DC	16	3.5	1.5E-4	7.1E-4	2.9E-3	1.4E-3	1.5E-3	2.4E-3						
Maine	14	8.3	6.6E-5	1.2E-4	1.8E-4	6.1E-3	7.4E-3	9.8E-3						
Massachusetts	4,610	3,707	1.9E-1	4.4E-1	7.4E-1	3.1E-1	8.7E+0	3.5E+2	4.4E-8	4.9E-4	7.4E-4	9.3E-7	5.3E-4	6.9E-3
New Hampshire	80	73.3				4.1E+0	4.1E+0	4.1E+0	8.3E-4	8.3E-4	8.3E-4	3.6E-3	3.6E-3	3.6E-3
New York	1,890	1,279	7.2E-7	1.9E-3	1.8E-1	2.1E-5	1.7E-3	4.3E-2	2.8E-4	7.1E-4	4.9E-2	1.2E-7	2.4E-5	7.5E-4
Rhode Island	4	1.8										1.7E-4	1.7E-4	5.2E-4
Texas	892	656.3	1.2E-2	4.3E-2	1.1E-1	5.0E-1	9.2E-1	1.3E+0	1.1E-1	3.2E-1	4.7E-1	2.8E-3	1.6E-1	9.3E+2
Vermont	0.1	0.1												

Radionuclide concentrations were observed to vary over 10 orders of magnitude, from about 0.01 to 10^{8} pCi/g. Most radionuclides, however, fall within a narrower range, i.e., 10^{2} to 10^{5} pCi/g. In some instances, several radionuclides are characterized by higher concentrations, ranging from 10^{6} to 10^{8} pCi/g, notably H-3, C-14, S-35, Mn-54, Co-58, Co-60, Ni-63, Kr-85, Sr-89, Sr-90, Y-91, Ru-106, I-125, Cs-137, Ce-144, Pm-147, Ir-192, and U-238.

5.4 Fuel Fabrication Facilities

This section presents a separate discussion of the waste generated by fuel fabrication facilities. Waste from fuel fabrication facilities are part of the industrial database; however, due to the unique and well-defined nature of this industry, a separate discussion and waste characterization are provided using sorts conducted by states, rather than regions.

Fuel fabrication facilities manufacture new fuel for nuclear power plants and research, test, and naval reactors, and also provide specialized services. Such services include refueling, supplying equipment, such as shipping casks and refueling tools, and, in some instances, spent-fuel storage. Two analyses were conducted to characterize waste generation practices, one to identify specific radionuclides and their concentrations, and the other to quantify total source and special nuclear materials.

Unlike the other categories of waste generators, it was not possible to access directly the low-level waste database characterizing fuel fabrication facilities. The data are imbedded within the industrial sector and can be accessed only indirectly. In order to obtain a sort representing fuel fabrication facilities, the search parameters were defined by States in which such facilities are located and the major radionuclide known to be associated with fuel fabrication, primarily uranium. The search, however, revealed the presence of other radionuclides, such as thorium, plutonium, depleted uranium, other transuranics (TRU), and source and special nuclear materials. It is believed that some of these radionuclides may be associated with other types of services, e.g., refueling support, refueling equipment refurbishing, shipping casks and refueling tools decontamination, etc. Accordingly, the results produced by these sorts incorporate some uncertainty and should be interpreted with caution.

The analyses characterizing radionuclide distributions were performed for non-brokered waste shipments to capture individual facility practices. Source and special nuclear materials analyses were conducted for both brokered and non-brokered shipments. As before, the analyses consider only Class A waste in both stable and unstable forms. The analyses were performed only for states in which such facilities are located (NRC91). These states include Pennsylvania, Virginia, Washington, Illinois, Connecticut, California, Missouri, North and South Carolina, Tennessee, and Oklahoma. The reason for focusing these searches at the State rather than Compact level is to minimize the inclusion of similar waste and radionuclides generated by other types of industrial facilities.

5.4.1 Special Nuclear and Source Materials

A breakdown of the total amounts of special nuclear and source materials is shown in Table 5-6. These results are also complemented with histograms and cumulative distribution curves shown in Appendix H. The histograms and cumulative distribution curves are contained at the end of each set of tables and figures characterizing the state.

The analyses captured up to 1,192 and 393 source and special nuclear materials shipping records, respectively. The analysis characterizes aggregate practices from 1986 to 1990 for all waste shipments to all three disposal sites. Materials shipped through brokers are not included in these analyses.

A review of Table 5-6 indicates that five states generate the greatest amounts of source and special nuclear materials. These states include Tennessee and South Carolina for source materials and Virginia, North and South Carolina, Oklahoma, and Tennessee for special nuclear materials. The amounts of source materials varied from 0.01 to 27,600 kg and from 0.01 to 175 g for special nuclear materials per shipment. On the average, each shipment consists of 230 kg source and 6 g of special nuclear materials. These states are responsible for the production of 63 percent of source and 99 percent of special nuclear materials, when compared to nationwide totals. Most of the materials are shipped directly to the disposal sites; less than ten percent of the facilities captured in the analyses use the services of waste brokers.

5.4.2 Fuel Fabrication Radionuclides

Separate analyses were performed for each of the 11 states cited above to provide a better perspective on the distribution of radionuclides making up source and special nuclear materials.

Table 5-6 Special Nuclear and Source Materials in Waste for Selected States - Aggregate Practices 1986 to 1990[a]

State	Source Material (kg)	Special Material (g)
Connecticut	3.43E+04	9.87E+02
Pennsylvania	1.76E+04	9.39E+02
Virginia	5.18E+04	2.41E+03
North Carolina	6.71E+03	1.52E+03
South Carolina	1.36E+06	4.93E+03
Illinois	2.74E+04	3.51E+00
Oklahoma	4.80E+04	2.47E+03
Missouri	8.69E+03	4.01E+02
Tennessee	5.84E+06	4.18E+03
Washington	1.04E+04	1.07E+02
California	8.28E+04	8.23E+02
Totals:	7.50E+06	1.80E+04
Average:	6.81E+05	1.71E+03
low:	6.71E+03	3.51E+00
high:	5.84E+06	4.93E+03
Typical shipment at the 50th percentile:		
range:	3 to 2,210	0.02 to 18.4
average:	230	6
Fraction of national total:	63%	99%[b]
National Totals all shipments:	1.20E+07	1.80E+04
Not brokered amounts:	1.16E+07	1.63E+04
fraction:	97%	91%

(a) Direct and brokered shipments to all three disposal sites (see text for details).

(b) Based on rounded off values. States which generate small amounts (e.g., on the order of few grams) would contribute to the remainder.

The analyses were performed at the shipping level for two reasons: a) to provide a more direct comparison of the data shown in Table 5-6, since these results also characterize shipping records, and b) because of the paucity of data at the container level.

The results are shown in Appendix H. The analyses captured from 26 to 578 shipping records. The most often cited radionuclides include Th-228, Th-230, Th-232, Th-234, U-234, U-235, U-236, U-237, U-238, Np-237, Am-241, Am-243, Cm-242, Cm-244, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, TRU, natural and depleted uranium, and natural thorium. Concentrations range from 0.03 pCi/g to 8.5×10^5 pCi/g. Most concentrations, however, fall within a narrower range, typically from 10^1 to 10^3 pCi/g. Typical shipment volumes range from about 11 to 28 m^3, with an overall average of 14 m^3, based on 2,107 shipping records.

5.5 Mixed Waste

Mixed waste, characterized by both hazardous chemical and radioactive properties, are generated during various activities when chemicals are introduced as cleaning agents or solvents. Activities that may result in the generation of mixed waste include R&D, laboratory analyses, and decontamination activities. Furthermore, actual generation rates are highly variable and are dependent upon specific facility practices.

Mixed waste generation rate estimates are based on the results of the National Profile on Commercially-Generated Low-Level Radioactive Mixed Waste (NUREG/CR-5938), as such waste is not being shipped to the disposal sites (NRC92). Consequently, the low-level database does not contain such information. The generation rates were weighted on a national basis to account for facilities which did not respond to the survey and those that were not queried during the survey (NRC92).

Tables 5-7 and 5-8 summarize the results of the 1990 National Profile for industrial waste generators. The results indicate that spent scintillation fluids, organics liquids, and other non-descript waste make up about 90 percent of the waste volume (see Table 5-7).

Table 5-8 summarizes the results of the 1990 National Profile by Compact regions and States. The results indicate that five Compacts generate about 91 percent of the estimated waste volume. They are the Midwest, Appalachian, Northeast, Southeast, and the Southwest Compacts. The total 1990 mixed waste volume for all regions has been estimated to be 50,430 ft^3 (NRC92).

Table 5-7 Industrial Generators Mixed Waste Profile - 1990 [a]

Waste Stream	Weighted Annual Generation Rate (ft^3/yr)	Percent
Liquid Scintillation Fluids	34,089	67.6
Waste Oils	531	1.0
Chlorinated Organics	494	1.0
Chlorinated Fluorocarbons	319	0.6
Other Organics	4,091	8.1
Metals (Pb, Hg, and Cr)	2,421	4.8
Corrosive Materials	1,442	2.9
Other Materials	7,043	14.0
Total	50,430	(b)

(a) Data extracted from NUREG/CR-5938, Table 4-6 (NRC92).
(b) Result may not add up to 100% due to rounding off.

5.6 Industrial Waste Generators - Class A Waste Description and Characteristics of Typical Industrial Waste Generators

The purpose of this section is to identify waste streams, volumes, and radionuclide distributions that best typify the individual waste generators within the industrial sector, as opposed to the previous sections, which emphasized the category as a whole.

Table 5-8 Industrial Facilities - 1990 Regional Mixed Waste Generation Profile[a]

Compact/State	Estimated Volume (ft^3)
Northwest	137
Rocky Mountain	395
Central States	25
Midwest	14,044
Central Midwest	1,694
Southeast	7,416
Northeast	8,632
Appalachian	12,443
Southwest	3,292
Maine	(b)
Massachusetts	1,225
New York	1,100
Texas	27
Vermont	(b)
New Hampshire	(b)
Rhode Island	(b)
District of Columbia	(b)
Puerto Rico	(b)
Total	50,430

(a) Data extracted from NUREG/CR-5938, Table 4-10 (NRC92).
(b) No data reported or facilities were not surveyed.

5.6.1 Waste Streams and Forms

The following waste streams are typical Class A waste produced by the industrial sector:

- dry solids,
- solidified liquids,
- sorbed aqueous liquids,
- compacted dry active waste,
- aqueous liquids in vials and sorbents,
- animal carcasses and other associated biological waste,
- non-compacted dry active waste,
- solidified oils and liquids,
- non-sorbed aqueous liquids, and
- non-aqueous liquids in vials and sorbents.

These waste streams are routinely produced by the majority of generators, make up a large fraction of the total waste volume, and have relatively well-characterized radiological and physical properties.

5.6.2 Waste Volume

Tables 5-9 and 5-10 present the averages and ranges of Class A waste volumes generated per facility. The values are estimates based on the total volume of waste and the number of unique waste generator codes identified within each Compact or State.

The data characterize overall practices from 1986 to 1990. For example, the average industrial generator located in the Northwest Compact produced 159 m^3 of waste over a 5-year period, from 1986 to 1990. The yearly average generation rate of 32 m^3 is derived by dividing the tabulated waste volume by five. As indicated in Table 5-10, the 5-year waste volume generated per facility in the Northwest Compact varies over four orders of magnitude, from 0.0153 to 6,640 m^3. At the 50th percentile, the aggregate waste volume is 0.637 m^3, yielding a yearly average of 0.13 m^3. Similar case comparisons can be made for other Compacts or States. For more details on waste volume distributions, refer to Appendix H.

These results should be interpreted with caution since the number of waste generators is based on unique identification codes assigned by the disposal sites and does not necessarily reflect the total number of facilities that actually produced the waste.

Table 5-9 Waste Volume Distribution Among Industrial Generators by Compact Regions and States[a]

Compact/State	No. of Unique Gen. Code	-- Waste Volume - m^3[b] -- Five-Year Total Vol. All Gen.	Ave. Gen. Five-Year Total Vol.	Ave. Gen. Yearly Volume --
Northwest	80	12,680	159	32
Rocky Mountain	67	297	4.4	0.9
Central	25	5,969	239	48
Midwest	237	4,366	18	3.7
Central Midwest	98	2,690	28	5.5
Southeast	202	23,140	115	23
Northeast	197	3,758	19	3.8
Appalachian	201	4,987	25	5.0
Southwest	404	5,352	13	2.7
District of Columbia	6	16	2.7	0.5
Maine	12	14	1.2	0.2
Massachusetts	120	4,600	38	7.7
New Hampshire	7	80	11	2.3
New York	166	1,761	11	2.1
Puerto Rico[c]	---	---	---	---
Rhode Island	3	3.5	1.2	0.2
Texas	45	892	20	4.0
Vermont	2	0.14	0.07	0.01
Total:	1,872	70,606	706	142
- Low:	2	0.14	0.07	0.01
- High:	404	23,140	239	7.7
- Average:	110	4,153	42	8.3
- Std. Dev.:	111	5,904	66	13.4

(a) Compiled from data given in Appendix F for all Class A waste.
(b) Aggregate and yearly average waste generation rates are rounded off. See text for details. To convert volume to to cubic feet, multiply cubic meter by 35.3.
(c) No waste disposed of during the reported period.

Table 5-10 Industrial Waste Volume Distributions Among Compact Regions and States[a]

	Waste Volume (m^3) at Percentile[b] Per Waste Generator (Aggregate Practices - 1986 to 1990)		
Compact/State	Minimum or 1st	50th	Maximum or 99th
Northwest	1.53E-02	6.37E-01	6.64E+03
Rocky Mountain	1.70E-03	2.41E-01	1.44E+02
Central	1.42E-02	6.37E-01	3.14E+03
Midwest	2.83E-03	3.26E-01	5.18E+02
Central Midwest	6.80E-03	3.34E-01	1.30E+03
Southeast	1.98E-03	7.31E-01	2.69E+03
Northeast	1.42E-02	6.46E-01	2.78E+02
Appalachian	1.19E-02	4.05E-01	6.80E+02
Southwest	1.13E-02	5.36E-01	2.99E+02
District of Columbia	1.19E-02	1.53E-02	8.50E+00
Maine	1.90E-02	4.02E-01	6.99E+00
Massachusetts	8.50E-03	8.50E-01	1.45E+03
New Hampshire	4.53E-02	6.37E-01	7.24E+01
New York	1.90E-02	4.70E-01	1.12E+02
Puerto Rico[c]	---	---	---
Rhode Island	5.30E-02	1.04E+00	2.39E+00
Texas	2.83E-03	1.33E+00	3.53E+02
Vermont	1.90E-02	1.90E-02	1.16E-01

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. See text for details.
(b) Yearly waste generation distributions may be approximated by dividing above values by 5. 1 m^3 = 35.3 cubic feet.
(c) No waste disposed of during the reported period.

The number of generators represents all that ever shipped waste from 1986 to late 1990 and does not necessarily reflect the current population size. It is not uncommon for some waste generators to have access to two disposal sites. In such instances, a single generator would have two identification codes. As a result, the total number of waste generators estimated by using their identification codes may be overestimated. Moreover, it is not possible to assess the extent of such practices.

5.6.3 Types and Quantities of Radionuclides Shipped for Disposal Per Waste Generator

Waste activity distributions, sorted by waste generators, are shown in Table 5-11. As can be noted, waste activity levels per waste generator vary significantly among Compact regions and States. Over the 5-year period covered, the activity of waste shipped per waste generator varies over ten orders of magnitude, from 1 uCi to 11,300 Ci. At the 50th percentile, aggregate waste activities are relatively more stable, spanning four orders of magnitude across all regions. For more details on waste activity distributions, refer to Appendix H.

The most often cited radionuclides include H-3, C-14, Na-22, P-32, P-33, S-35, Cl-36, Ca-45, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ge-68, Ge-67, Ga-68, Se-75, Rb-86, Sr-85, Kr-85, Y-88, Y-90, Sr-90, Tc-99, Ru-103, Ru-106, Cd-109, Ag-110m, Sn-113, In-114m, Sn-113, I-125, I-129, Ba-133, Cs-134, Cs-137, Ce-139, Ce-141, Gd-153, Tl-201, Hg-203, Po-210, Ra-226, Th-228, Th-230, Th-232, Th-234, U-234, U-235, U-236, U-237, U-238, Np-237, Am-241, Am-243, Cm-242, Cm-244, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, natural and depleted uranium, and natural thorium.

5.6.4 Decontamination Operations - Projections

As with the other sectors, industrial facilities generate waste as a result of routine and special operations and also as a result of periodic decontamination activities. The waste volume estimates presented here reflect all of these activities, but it is impossible to resolve this waste stream from the database. The following discussion is based on other sources of information to provide some insight into the potential contribution of such activities to the overall volume of waste. The data presented here reflect generic projection rates, rather than actual generation practices. Table 5-12 presents an example of the waste volumes associated with the decontamination and refurbishment of two areas within a facility (NRC80b).

Table 5-11 Industrial Waste Activity Distributions Among Compact Regions and States[a]

Compact/State	Waste Activity (Ci) at Percentile[b] Per Waste Generator (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	2.00E-05	1.15E-01	2.22E+02
Rocky Mountain	1.00E-06	8.50E-03	1.28E+01
Central	0.00E-00	9.28E-02	1.15E+01
Midwest	1.00E-06	2.05E-02	1.00E+02
Central Midwest	1.00E-06	2.21E-02	4.57E+01
Southeast	1.00E-05	2.87E-02	2.64E+02
Northeast	1.42E-02	6.46E-01	2.78E+02
Appalachian	3.00E-05	1.86E-02	1.59E+02
Southwest	1.00E-06	1.13E-02	1.67E+03
District of Columbia	2.40E-05	1.50E-02	1.64E+01
Maine	3.68E-04	2.44E-02	7.05E-01
Massachusetts	4.10E-05	4.60E-02	1.20E+02
New Hampshire	2.23E-04	4.40E-02	2.63E+00
New York	3.30E-05	1.00E-02	3.18E+01
Puerto Rico[c]	---	---	---
Rhode Island	9.16E-03	2.00E-01	2.39E+01
Texas	4.00E-06	1.13E-01	1.13E+04
Vermont	4.30E-05	4.30E-05	1.89E-02

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. Entries with 0.00E-00 values indicate that the database did not have any data for those records. See text for details.

(b) Yearly waste activity distributions may be approximated by dividing above values by 5. 1 Ci = 3.7×10^{10} Bq.

(c) No waste disposed of during the reported period.

Table 5-12 Decontamination Waste Volume Projections for Industrial and Fuel Cycle Facilities

Facility	Assumed Lab Space (m^2)	Waste Volume (m^3)	No. of Containers Drums	Boxes
Radio-chemical/ pharmaceutical laboratory[a]:	50 - 120	20 - 45	10 - 20	80 - 130
Sealed Source manufacturer[a]:	50 - 60	20 - 30	15 - 30	60 - 100
Fuel Fabrication Facility - Generic Study[b]:				
- Chemical and Metallurgical Laboratory:	380	120	-- no data --	
- Hot Maintenance Shop:	400	95	-- no data --	
Fuel Fabrication Facility - Actual Results[c]:	2,081 - all areas			
- TRU Waste:	--	524	736	- na -
- Non-TRU Waste:	--	47	na	220

(a) Data extracted from NUREG/CR-1754 (NRC81c). All values are rounded up. Waste volume projections characterizing D&D volume estimates for generic facilities. Estimates are based on the decontamination of a single room and internal facilities such as hoods, bench tops, sinks and drains, ventilation duct work, glove boxes, filter housings, and the associated trash and solidified liquids. To convert volume to cubic feet, multiply cubic meter by 35.3.

(b) Data extracted from NUREG/CR-1266 (NRC80b). All values are rounded up. Waste volume projections characterizing decontamination volume estimates for generic facilities.

(c) Data characterize decontamination and decommissioning waste volumes of the former Westinghouse Nuclear Fuel Facility located at Cheswick, PA (DEN84).

In this example, a laboratory and maintenance shop were selected for illustrative purposes. The resulting waste volumes vary from about 95 to 120 m^3. The second case is based on decommissioning data of a former fuel facility (DEN84). As is anticipated, the waste volume associated with such a large scale decontamination and decommissioning effort is higher. In this case, a total of 571 m^3 of waste were produced for both TRU and non-TRU waste forms.

5.7 Geographic Distribution and Demographics of Industrial Waste Generators

5.7.1 Geographical Distribution

Industrial waste generators are located in both urban and rural areas. There are no specific reasons for the location of individual facilities. Some of the factors which may have influenced a facility from relocating or providing a service are primarily due to business opportunities. In other instances, some facilities were drawn to an area because of the availability of a qualified labor force and support resources.

The locations of the major industrial waste generators are identified by city, county, and state (see Appendix G-1). By definition, industrial waste generators also include fuel fabrication facilities and their support organizations servicing nuclear utilities. Also included in the industrial sector are waste brokers and processors. A separate listing of waste brokers and processors is provided in Appendix G-3. Industrial waste generators may have more than one location identified under the same NRC and/or Agreement State license. However, it does not follow that all identified locations necessarily generate waste. The data contained in Appendix G-1 were extracted from periodic reports issued by Compacts, States, and the NRC. Some Compacts or States, however, did not provide this information, as some generators and states have deemed this type of data to be confidential.

5.7.2 Demographics

Population data were obtained from the Bureau of Census based on the 1990 census results (DOC92). The data were sorted to tally population counts by Compact, State, and county, when identified. Population data were compiled for each of the nine Compacts and nine unaffiliated States (see Appendix G-2).

6.0 MEDICAL FACILITIES

6.1 Introduction

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. Accordingly, the discussion that follows applies to the other categories of waste generators, especially those in the academic and government sectors, and the radio-pharmaceutical portion in the industrial category. See Sections 3.0, 4.0, and 5.0 for academic, government, and industrial generators, respectively.

6.2 Characterization of Biomedical Waste Generator Activities

This section presents a summary description of medical waste based on information and data contained in published reports. This section establishes the background needed in support of the more detailed characterization, which is provided in subsequent sections using data available from the database.

Low-level radioactive wastes produced by medical facilities are associated with the use of radioactive materials in the practice of nuclear medicine and while conducting medical research and clinical tests. Nuclear medicine involves administering discrete amounts of radioactive materials for the purpose of assessing organ functions and uptake (e.g., thyroid); imaging the distribution of a tracer within an organ (e.g., detecting the presence of a tumor); estimating the volume and density of tissues in organs (e.g., blood cell and plasma volumes); and measuring protein, steroid, or hormone levels (NCR82). Such studies can be performed by oral or intravenous administration, or in-vitro cell cultures or tissue samples. Radio-labeled compounds can be introduced in their elemental forms, as colloids or complexed with other elements, or as organic compounds targeting a specific organ.

Medical research involves the use of radioactive materials in biochemical, biophysical, and physiological investigations. Such investigations involve the use of radioactive tracers to study drug metabolism, bio-kinetics, and reactions of subjects to varying doses. The results of such studies are used to collect information to support drug development, new drug applications, and secure Food and Drug Administration approvals.

Radiopharmaceutical products are available in a variety of kits (e.g., as unit-dose, radio-immunological assay kits [RIA]) which contain all the necessary components for administration (NEN91, ICN91, AME91). Such kits typically contain varying levels of radioactivity, from very small amounts (e.g., up to several hundred microcuries) to relatively large quantities (e.g., several hundred millicuries). Other kits, however, give the end-user the capability to prepare the administrative dose by using a dispensing unit (e.g., a Mo-99/Tc-99m generator). Generators usually contain relatively larger quantities of radioactivity (e.g., from several hundred millicuries to a few Curies). For some medical procedures, e.g., positron emission tomography, short-lived nuclides are produced using a cyclotron.

The number of nuclear medicine procedures performed varies significantly as new diagnostic procedures and imaging techniques are developed. For example, from 1972 to 1982, the frequency of all diagnostic procedures increased from 16 to 32 per thousand of population, or about 8 million per year, assuming a U.S. population of 250 million (NCR89a). Over these years, some procedures have increased, while others have decreased. For example, the number of brain scans decreased, while those for liver, bone, thyroid, urinary organs, and pulmonary and cardio-vascular function tests increased. The mix of nuclear medicine procedures has also changed because of the use of computer tomography (CAT scans) and ultra-sound techniques. It is also not clear whether the increasing use of such techniques and the advent of magnetic resonance imaging (MRI) will displace some of the nuclear diagnostic procedures currently being used.

Finally, it is common practice for medical waste generators that generate small amounts of waste to secure the commercial services of waste brokers. Waste brokers provide waste containers, packaging materials, paperwork and forms, labels, etc., and arrange for pick-up, transportation, and ultimate disposal at one of the three operating low-level waste sites.

In reviewing the information contained in this section, the reader is cautioned that the database incorporates some inherent limitations that should be recognized before reaching any conclusions. Some of these limitations are associated with waste generator disposal practices, while others are due to differences in how the data are coded by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

6.2.1 Waste Streams and Forms

Medical facilities generate a wide spectrum of waste, including dry solids, biological tissues, compressible and non-compressible materials, and aqueous and organic liquids. Some liquids may be solidified or immobilized in stabilization or absorption media.

The following list summarizes the primary types of waste streams routinely generated by the medical sector (NRC81a, NRC81b, NRC82, NRC83a, NRC83b, NRC86a, NRC92, DOE87, DOE90a, EPA88). The most frequently reported biomedical waste streams or materials include:

Type of Waste	Government	Academic	Medical	Industrial
Compacted trash	x	x	x	x
Laboratory		x	x	
Biological		x	x	
Animal carcasses		x		
Absorbed liquids	x	x	x	x
Sealed sources			x	x
Hardware	x			x
Depleted uranium				x

This breakdown is based on the waste streams or materials most often cited by the three commercial low-level waste disposal sites (EGG90). This information is drawn from the shipping manifest forms (see example in Appendix A) currently being used by the three disposal sites (MUN91, USE88, CNS90). The low-level waste literature, however, indicates that waste form distributions are more extensive than that shown above (NRC90, IAE90, NRC81a, NRC81b, NRC82, EPA88, DOE90a).

A key factor in characterizing low-level waste is its physical and chemical form. The waste generators provide on the manifest form some information of the properties of the waste. However, this information is not always standardized. The concern regarding waste properties stems from NRC requirements that are intended to protect the health and safety of personnel and ensure the long-term stability of the disposal site. Generators are disposing Class A waste using various agents to enhance its stability, even though 10 CFR Parts 61.55 and 61.56 do not require it, unless it is commingled with Class B or C waste. Disposal sites have followed through by identifying and coding such waste as "stable" or "unstable." A list of solidification and sorbent agents is given in Section 2.2, Table 2-7.

6.2.2 Radionuclides and Volumes of Waste Shipped for Disposal

A broad distribution of radionuclides are routinely used by the medical industry. The selection of a specific radionuclide depends upon the types of tests or research objectives, methods applied to introduce or administer the radioactivity, and techniques used to measure the outcome of the procedures.

The majority of the radionuclides used by the medical sector are produced by research reactors, while short-lived nuclides (e.g., C-11, N-13, F-18, Ga-68, etc.) are made with cyclotrons. Because of the short-half lives, cyclotron facilities must be located near the point of use. The most frequently reported biomedical radionuclides include:

Government	Academic	Medical	Industrial
Co-60	I-125	Cr-51	Nat-Th
Fe-55	H-3	H-3	Nat-U
Mn-54	S-35	I-125	U-238
Ni-63	C-14	S-35	C-14
Co-58	Cr-51	C-14	H-3
C-14	P-32	Co-57	Cs-137
	Ca-45	Fe-59	Co-60
		P-32	Pu-241
		U-238	Ra-226

This listing is based on the most often cited radionuclides by the three commercial low-level waste disposal sites (EGG90). Tables 6-1 and 6-2 present listings of radionuclides used by the medical industry. Table 6-1 presents information about typical amounts of radioactivity used in general procedures, principal applications, and radiological half-lives. The quantities of radioactive material used per application vary among facilities and institutions. This information is presented only for the purpose of providing some perspective about the amounts of radioactivity routinely used and should not be interpreted as absolute. Table 6-2 lists the same radionuclides rearranged by half-life groupings. About 24% of the nuclides listed, or 23, have half-lives greater than one year, and nine have half-lives greater than 100 years.

Waste volumes and activity levels shipped for disposal by medical waste generators and all waste generators (excluding nuclear utilities) are shown in Table 6-3 (NRC90, DOE90b). The medical sector contributes less than one percent of the activity and only a few percent of the volume of the waste shipped for disposal by all waste generators, excluding nuclear utilities. For the four years of data shown, waste activity peaked in 1989 for medical waste generators.

Table 6-4 presents the total waste activity and volume received at the three disposal sites from 1986 to 1990. Over 92 percent of the total waste activity is generated by the Midwest, Northeast, Appalachian, and Southwest Compacts, and the States of New York and Massachusetts.

Table 6-1 Principal Radionuclides Used by the Bio-Medical Industry[a]

Radionuclide	Half-Life		Principal Application	Activity[b,c] Application
H-3	12.4	y	Clinical measurement	up to 150 uCi
			Biological research	up to 1.5 Ci
			Labelling	" "
N-13	10	m	Clinical measurement	
C-14 &	5730	y	Biological research	up to 30 mCi
C-11	20	m	Labelling	up to 300 uCi
O-15	2	m	Biological research	
F-18	1.8	h	Biological research	
Na-22	2.6	y	Clinical measurement	up to 100 uCi
			Biological research	up to 2 mCi
Na-24	15.0	h	Clinical measurement	up to 150 mCi
			Biological research	up to 2 mCi
Al-26	7.2E+5	y	Biological research	
P-32	14.3	d	Clinical therapy	up to 5 mCi
P-33	25.4	d	Biological research	up to 1.5 mCi
S-35	87.4	d	Clinical measurement	up to 150 mCi
			Biological research	up to 25 mCi
Cl-36	3.0E+5	y	Biological research	up to 150 uCi
K-42 &	12.4	h	Clinical measurement	
K-43	22.6	h	" "(b)	
Ar-41	1.8	h	Clinical measurement	
Ca-45 &	163	d	Clinical measurement	up to 3.0 mCi
Ca-47	4.5	d	Biological research	up to 30 mCi
Sc-46	83.8	d	Biological research	up to 10 mCi
Cr-51	27.7	d	Clinical measurement	up to 150 uCi
			Biological research	up to 10 mCi
Mn-54	312.5	d	Biological research	up to 1 mCi
Mg-56	2.6	h	Biological research	
Co-57,	270.9	d	Clinical measurement	up to 10 uCi
Co-58 &	70.8	d	Biological research	up to 10 mCi
Co-60	5.3	y	" "	up to 10 mCi
Cu-64	12.7	h	Clinical measurement	
			Biological research	
Fe-59,	44.5	d	Clinical measurement	up to 1.5 mCi
Fe-52 &	8.3	h	Biological research	" "
Fe-55	2.7	y	" "	" "
Ni-63	100.1	y	Biological research	up to 10 mCi
Zn-65	243.9	d	Clinical measurement	up to 5 mCi
Ge-68	288	d	Biological research	
Se-75	119.8	d	Clinical measurement	up to 1.5 mCi

Table 6-1 Principal Radionuclides Used by the Bio-Medical Industry[a], Cont'd

Radionuclide	Half-Life		Principal Application	Activity[b,c] Application
Ga-66 &	9.4	h	Clinical measurement	up to 10 mCi
Ga-67,	78.3	h	" "	" "
Ga-68	68.0	m	" "	" "
Rb-81 &	4.6	h	Clinical measurement	
Kr-81m,	13.3	s	" "	
Kr-85	10.7	y	Clinical measurement	
Br-82	35.3	h	Clinical measurement	
Rb-82	1.3	m	Clinical measurement	
Rb-84	32.8	d	Clinical measurement	
Rb-86	18.7	d	Clinical measurement	up to 10 mCi
Sr-85	64.8	d	Clinical measurement	up to 300 uCi
			Biological research	up to 10 mCi
Sr-87m	2.8	h	Clinical measurement	
Sr-89	50.5	d	Clinical therapy	up to 15 mCi
Sr-90	29.1	y	Biological research	up to 1 mCi
Y-90	64.0	h	Clinical measurement	up to 30 uCi
Y-87	80.3	h	Biological research	
Y-88	106.6	d	Clinical therapy	
Mo-99	66.0	h	Mo-Tc Generator	up to 3 Ci
Tc-99m	6.0	h	Clinical measurement	up to 20 mCi
			Biological research	" "
Nb-95	35.2	d	Biological research	up to 1 mCi
Ru-103 &	39.3	d	Biological research	up to 10 mCi
Ru-106	368.2	d	" "	" "
Cd-109 &	464	d	Clinical measurement	up to 1 mCi
Cd-115m	44.6	d	Biological research	" "
Ag-110m	249.9	d	Biological research	up to 1 mCi
In-111,	2.8	d	Clinical measurement	up to 15 mCi
Sn-113,	115.1	d	Biological research	up to 5 mCi
In-113m &	99.4	m	Biological research	
In-114m	49.5	d	" "	up to 10 mCi
I-121,	2.1	h	Clinical measurement	up to 600 uCi
I-123,	13.2	h	Biological research	up to 1.5 mCi
I-125,	60.1	d	Clinical therapy	up to 300 mCi
I-130,	12.4	h	Clinical measurement	up to 600 uCi
I-129	1.6E+7	y	" "	up to 10 uCi
I-131 &	8.0	d	" "	up to 300 mCi
I-132	2.3	h	" "	up to 1.5 mCi
Xe-127 &	36.4	d	Clinical measurement	up to 10 mCi
Xe-133	5.2	d	Clinical measurement	up to 50 mCi
Ba-133	10.7	y	Biological research	

Table 6-1 Principal Radionuclides Used by the Bio-Medical Industry[a], Cont'd

Radionuclide	Half-Life	Principal Application	Activity[b,c] Application
Cs-129,	32.1 h	Clinical measurement	
Cs-131,	9.7 d	Biological research	
Cs-132,	6.5 d	Clinical therapy	
Cs-134 &	2.1 y	" "	
Cs-137	30.0 y	" "	
Ce-139 &	137.7 d	Biological research	up to 25 mCi
Ce-141	32.5 d	" "	
Ce-147	65 s	" "	
Pm-147	2.6 y	Biological research	up to 10 mCi
Gd-153	242.0 d	Biological research	up to 1 mCi
Yb-169	32.0 d	Clinical measurement	
Ir-192	74.0 d	Biological research Clinical therapy	
Hg-197	64.1 h	Clinical measurement	
Hg-203	46.6 d	Biological research	
Au-198	2.7 d	Clinical therapy	up to 300 mCi
Au-195	183 d	" " Biological research	" "
Tl-201 &	73.0 h	Clinical measurement	up to 20 mCi
Tl-204	3.8 y	Biological research	up to 100 uCi
Bi-206	6.2 d	Clinical measurement Biological research	
Po-210	138.4 d	Biological research	
Ra-226	1600 y	Clinical therapy	up to 10 mCi
Th-228	1.9 y	Biological research	
Th-232	1.4E+10 y	Biological research	
U-238	4.5E+9 y	Biological research	
Am-241	432.2 d	Biological research	

(a) Data extracted from NCR89a, NCR82, ICR77, ICR83, IAE90, NEN91, AME91, ICN91, HEW70, and KOC81. See text for details.
(b) Possible range of radionuclide activity used in general procedures or research activities. All values are approximate since actual practices vary among facilities and institutions. Some values were taken from the cited literature while others were obtained from vendors by telephone conversations and by reviewing product catalogs.
(c) To convert activity in SI units, multiply Ci by 3.7×10^{10} Bq; mCi by 3.7×10^{7} Bq, and uCi by 3.7×10^{4} Bq.

Table 6-2 Principal Radionuclides Used by the Bio-Medical Industry Arranged by Half-Lives[a]

<24 hours	<7 Days	<100 Days	<1 Year	>1 Year	>100 Years
C-11	Ca-47	P-32	Ca-45	H-3	C-14
N-13	Ga-67	P-33	Mn-54	Na-22	Al-26
O-15	Br-82	S-35	Co-57	Co-60	Cl-36
F-18	Y-87	Sc-46	Zn-65	Fe-55	Ni-63
Na-24	Y-90	Cr-51	Ge-68	Kr-85	I-129
Ar-41	Mo-99	Co-58	Se-75	Sr-90	Ra-226
K-42	In-111	Fe-59	Y-88	Ru-106	Th-232
K-43	Xe-133	Rb-84	Ag-110m	Cd-109	U-238
Fe-52	Cs-129	Rb-86	Sn-113	Ba-133	Am-241
Mg-56	Cs-132	Sr-85	Ce-139	Cs-134	
Cu-64	Hg-197	Sr-89	Gd-153	Cs-137	
Ga-66	Au-198	Nb-95	Au-195	Pm-147	
Ga-68	Tl-201	Ru-103	Po-210	Tl-204	
Rb-81	Bi-206	Cd-115m		Th-228	
Kr-81m		In-114m			
Rb-82		I-125			
Sr-87m		I-131			
Tc-99m		Xe-127			
In-113m		Cs-131			
I-121		Ce-141			
I-123		Yb-169			
I-130		Ir-192			
I-132		Hg-203			
Ce-147					
n= 24	14	23	13	14	9
%= 24.7	14.4	23.7	13.4	14.4	9.4

(a) See text for details.

Table 6-3 Yearly Activity and Waste Volumes Generated by Medical Waste Generators[a]

Year		Medical	Total (Except Utilities)
1986	Volume (m^3)	6.75E+2	2.18E+4
	Percent	3.1	100
	Activity (Ci)	2.60E+1	6.32E+4
	Percent:	0.04	100
1987	Volume (m^3)	8.00E+2	2.48E+4
	Percent	3.3	100
	Activity (Ci)	3.55E+1	4.98E+4
	Percent:	0.07	100
1988	Volume (m^3)	5.96E+2	1.75E+4
	Percent	3.4	100
	Activity (Ci)	8.09E+1	4.62E+4
	Percent	0.2	100
1989	Volume (m^3)	9.66E+2	2.21E+4
	Percent	4.3	100
	Activity (Ci)	1.49E+2	1.41E+5
	Percent	0.1	100
1990	Volume (m^3)	6.45E+2	1.42E+4
	Percent	4.5	100
	Activity (Ci)	5.95E+1	1.14E+5
	Percent	0.05	100
TOTAL			
	Volume (m^3)	3.68E+3	1.00E+5
	Percent	3.7	100
	Activity (Ci)	3.51E+2	4.18E+5
	Percent	0.08	100

(a) Data extracted from NUREG-1418 (NRC90), on-line MIMS service, and the 1989 State-by-State Assessment (EGG90). 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 6-4 Medical Waste Volume and Activity - Aggregate Practices 1986 - 1990 [(a)]

Compact/State	-- Volume -- Vol. (m^3)	Percent	-- Activity -- Act. (Ci)	Percent
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. 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.

6.3 Detailed Characterization of Waste Properties

The detailed characterization of medical waste is based on information obtained from the National Low-Level Waste Management Program database, known as "MIMS" (EGG90). This information was also supplemented by data obtained through direct access with the MIMS system. Low-level waste data were made available in electronic files from EG&G Idaho, Inc. (MUN90, MUN91) for all three disposal sites, namely Barnwell, SC, Beatty, NV, and Richland, WA. The supplied electronic files contain manifest data at the shipment level for five years, from 1986 to 1990. However, data at the container level were only available for Beatty and Richland from 1988 to 1990. In both cases, the 1990 data reflect information posted by the end of November 1990.

A description of the program, discussion on data manipulation and selection, and validation process are provided in Section 2.0 and Appendix B. Sample copies of shipping manifest forms can be found in Appendix A.

6.3.1 Waste Characterization - Container Level

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

- 1 shipping manifest
- 109 container records
- 23 cubic meters of waste
- 17,120 kg of waste, 0.74 g/cm^3 average density
- 3.3 Ci of total activity, 0.14 Ci/m^3

On inspection, Table 6-3 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered and Classes A, B and C, generated from 1988 to 1990 was 2,207 cubic meters and 289.4 Ci, respectively. Accordingly, this search represents about one percent of the volume and 1.1 percent of the total activity of waste shipped by medical waste generators. More importantly, the sort captured only one shipping manifest. The reason such a small percentage was captured is due to the fact that medical waste generators use waste brokers and rarely ship waste directly to disposal facilities. Accordingly, the data captured in this sort may not be representative of the medical sector. Interestingly, the average gross radionuclide concentration is 0.13 Ci/m^3, based on 1988 to 1990 data, and is in close agreement with that shown above for the data sort.

Exhibit 6-1 presents the concentration distributions of the principal radionuclides contained in the 109 containers captured by the sort. In summary, the results of the search revealed the following concentration distributions for the principal radionuclides:

Radionuclide	Class A Limits	Activity Shipped (Ci)	Concentration (Ci/m3) Median	Average	1%ile	10%ile	90%ile	99%ile
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
	Total	3.28E+00						

As indicated in Exhibit 6-1, the sort captured 34 radionuclides. However, the above radionuclides constitute 3.28 of the 3.3 Curies (or 99%) captured by the sort.

The results reveal that average radionuclide concentrations vary by three orders of magnitude, from 1.1×10^{-4} to 7.5×10^{-2} Ci/m^3. At the 99th percentile, the concentrations even more, from $1.6 \times 10^{+0}$ to 3.5×10^{-4} Ci/m^3. The 1st percentile values are of little use because a default lower limit cutoff of 1 uCi is used in the database, which translates to a concentration of 4.7E-06 Ci/m^3 in a 55-gallon drum.

Appendices C and D present all the non-brokered, Class A, container level data sorted by Compact or unaffiliated State and waste streams. Using the data obtained from Appendix C, Table 6-5 presents a comparison of selected radionuclide concentration distributions for specific waste streams and different regions of the United States.

Appendix D presents information similar to that provided in Appendix C, except sorted by waste streams only (i.e., the data are not sorted by Compact or State). In addition, the results are presented in the form of histograms and cumulative distribution curves for each of the principal radionuclides captured in each sort.

Each sort provided in Appendix D includes a summary sheet, which provides additional information, including the total number of shipping and container records captured in the sort, weight of waste shipments, and total and fractional waste volumes and activity levels. These data provide an indication of the representativeness of each sort.

EXHIBIT 6-1

MEDICAL WASTE - CONTAINER LEVEL ANALYSIS

Number of shipping records captured:	1
Number of container records captured:	109
Number of isotope records captured:	716
Total activity of containers (Ci):	3.31E+00
Total volume of containers (m^3):	2.32E+01
Total weight of containers (kg):	1.71E+04
Total density (g/cm^3):	7.39E-01
Total concentration (Ci/m^3):	1.43E-01
Total concentration (pCi/g):	1.93E+05

Exhibit 6-1 (Continued)

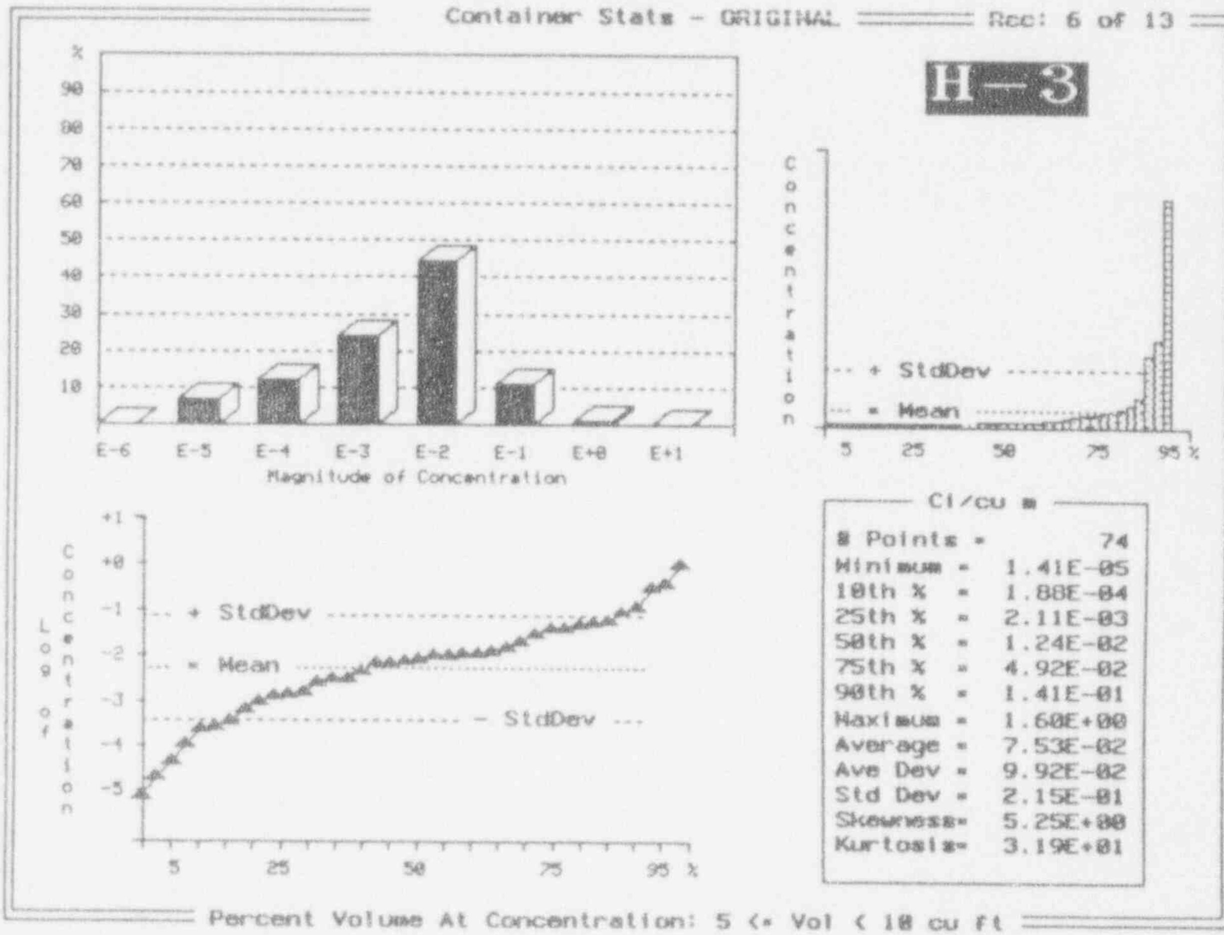

Exhibit 6-1 (Continued)

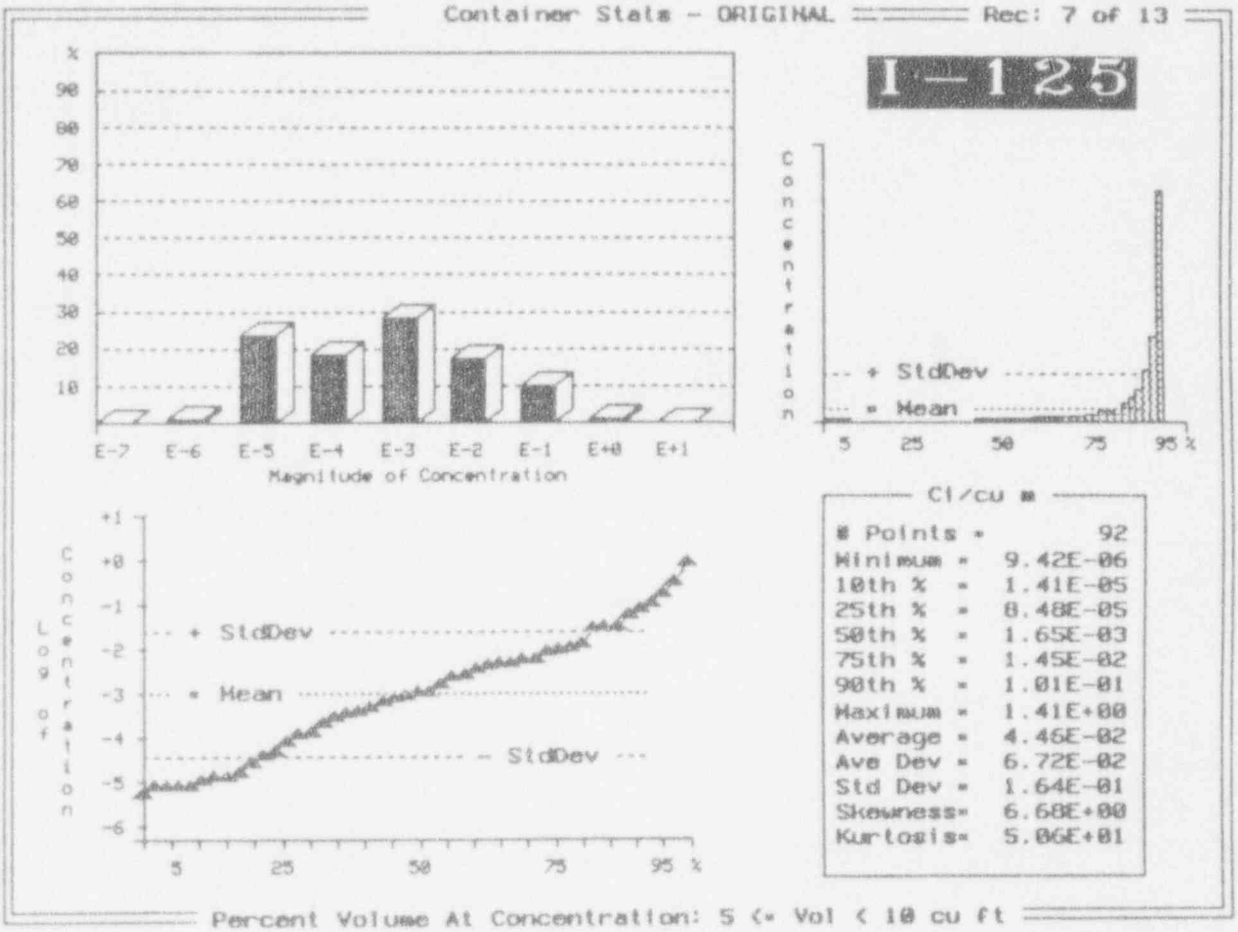

Exhibit 6-1 (Continued)

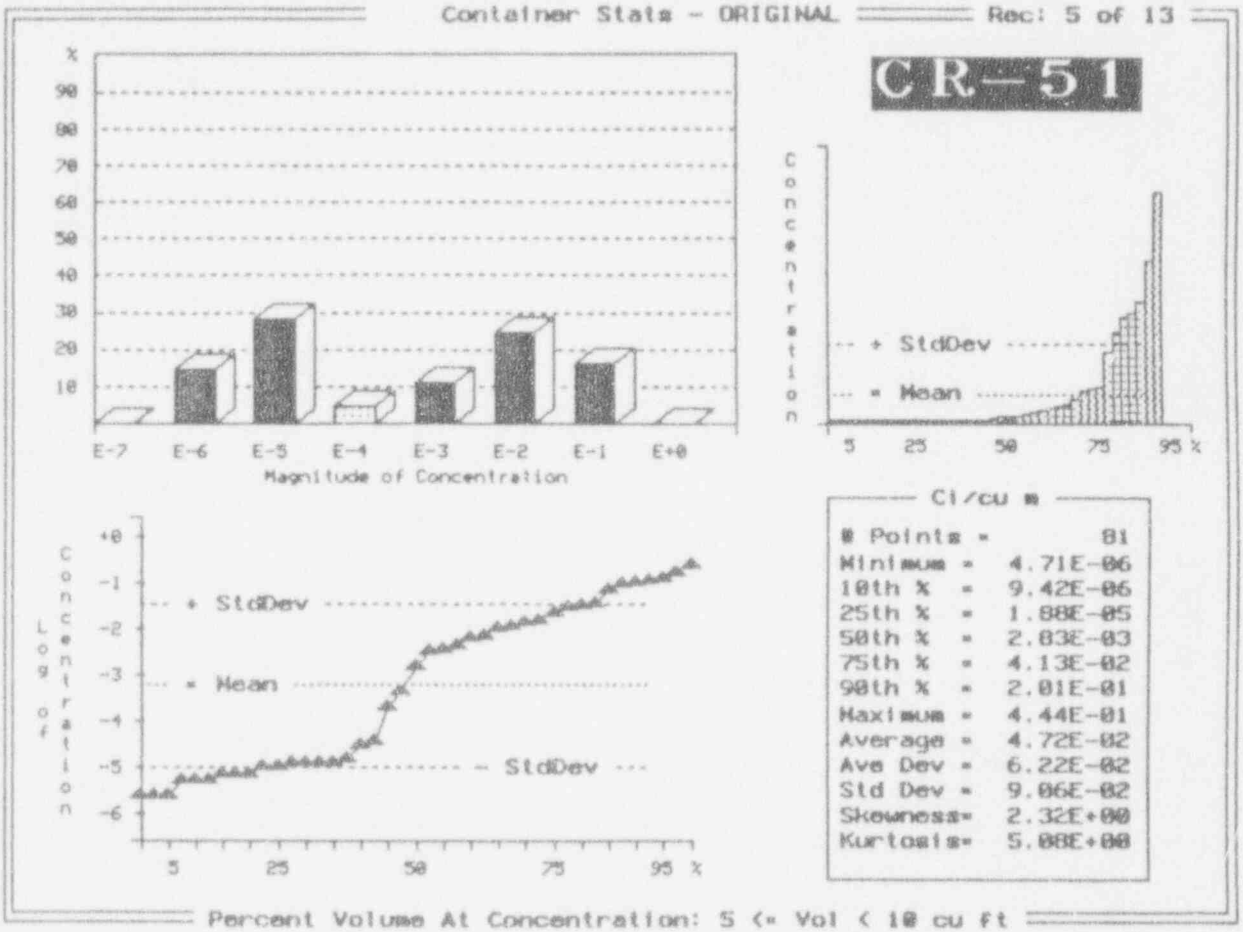

Exhibit 6-1 (Continued)

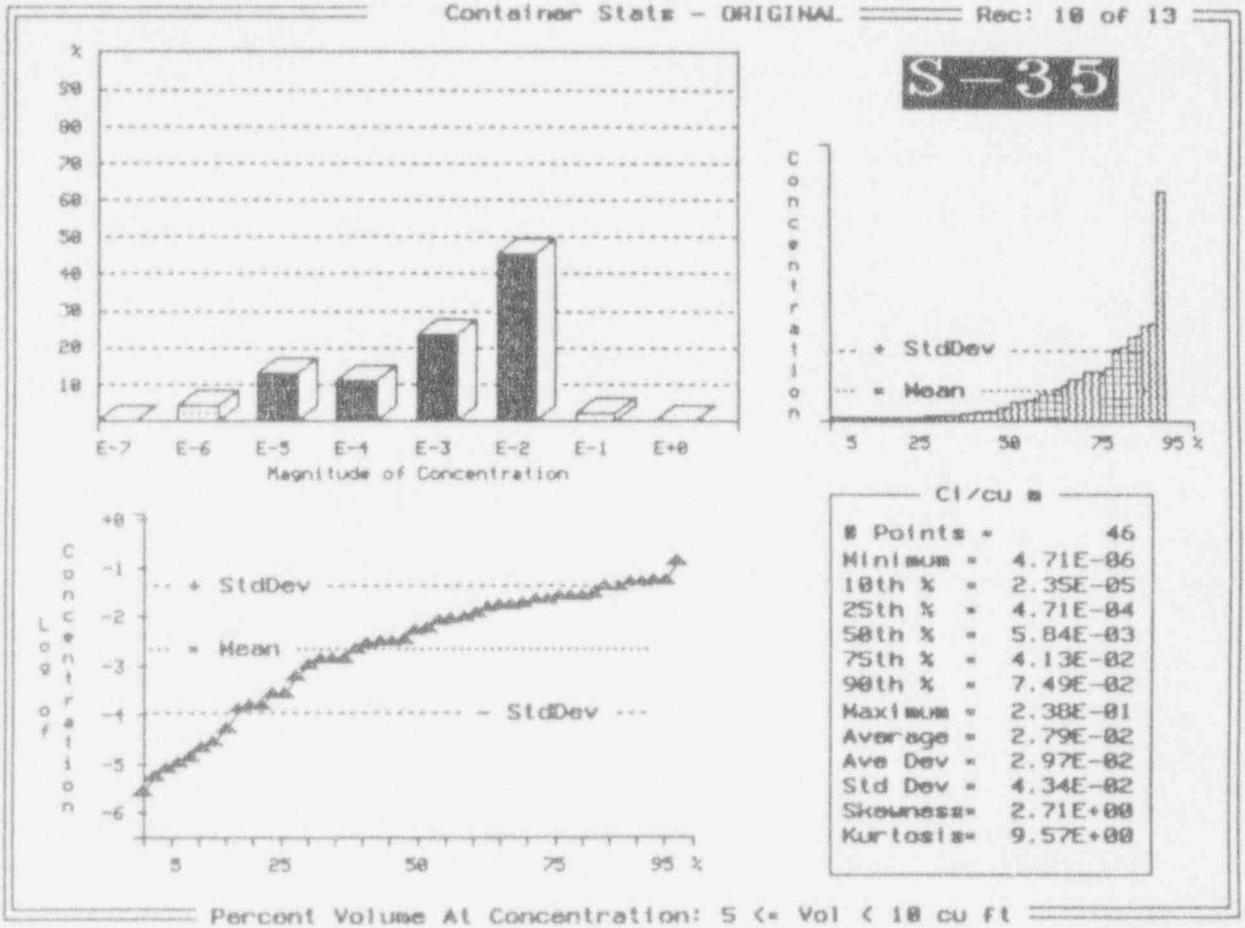

Exhibit 6-1 (Continued)

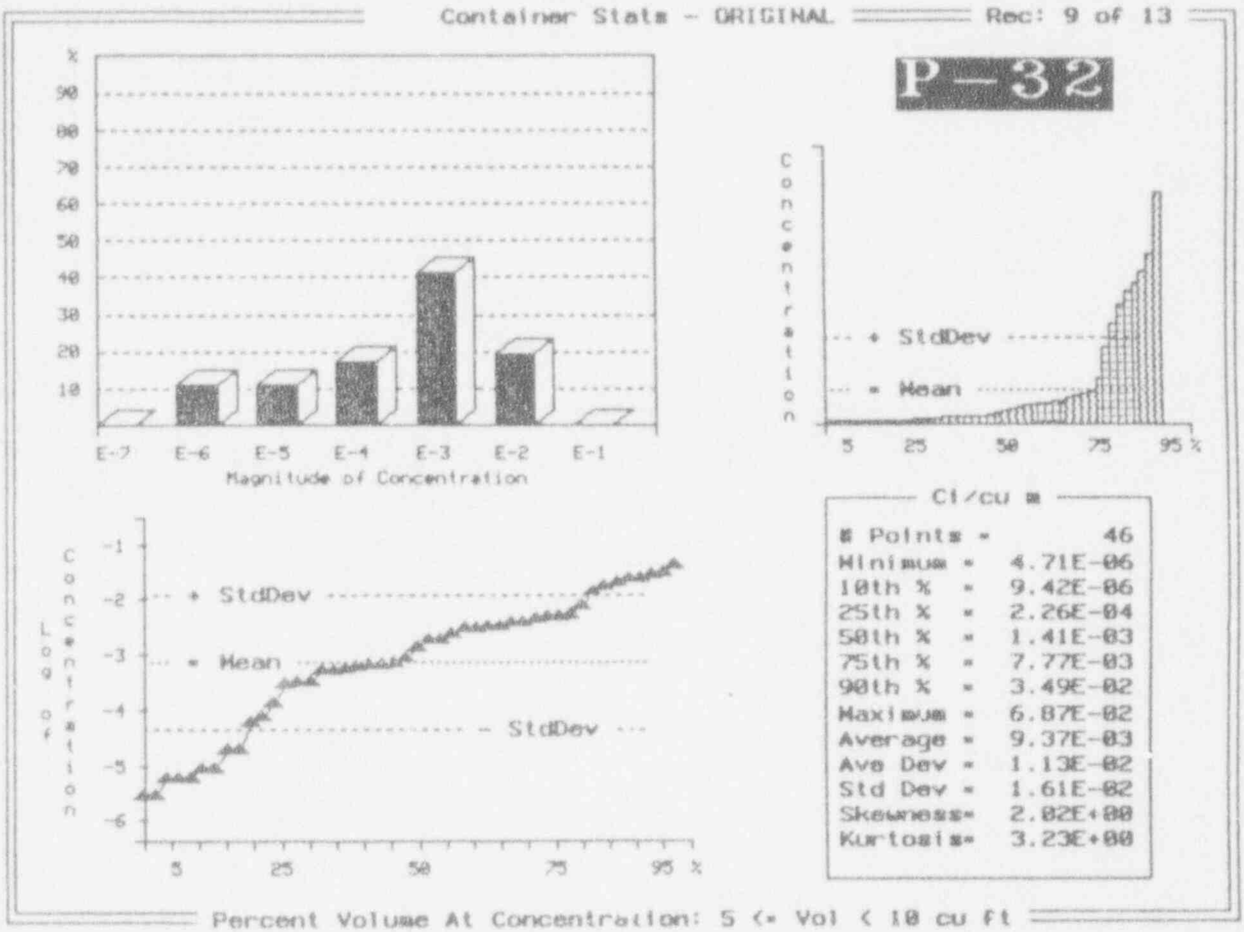

Exhibit 6-1 (Continued)

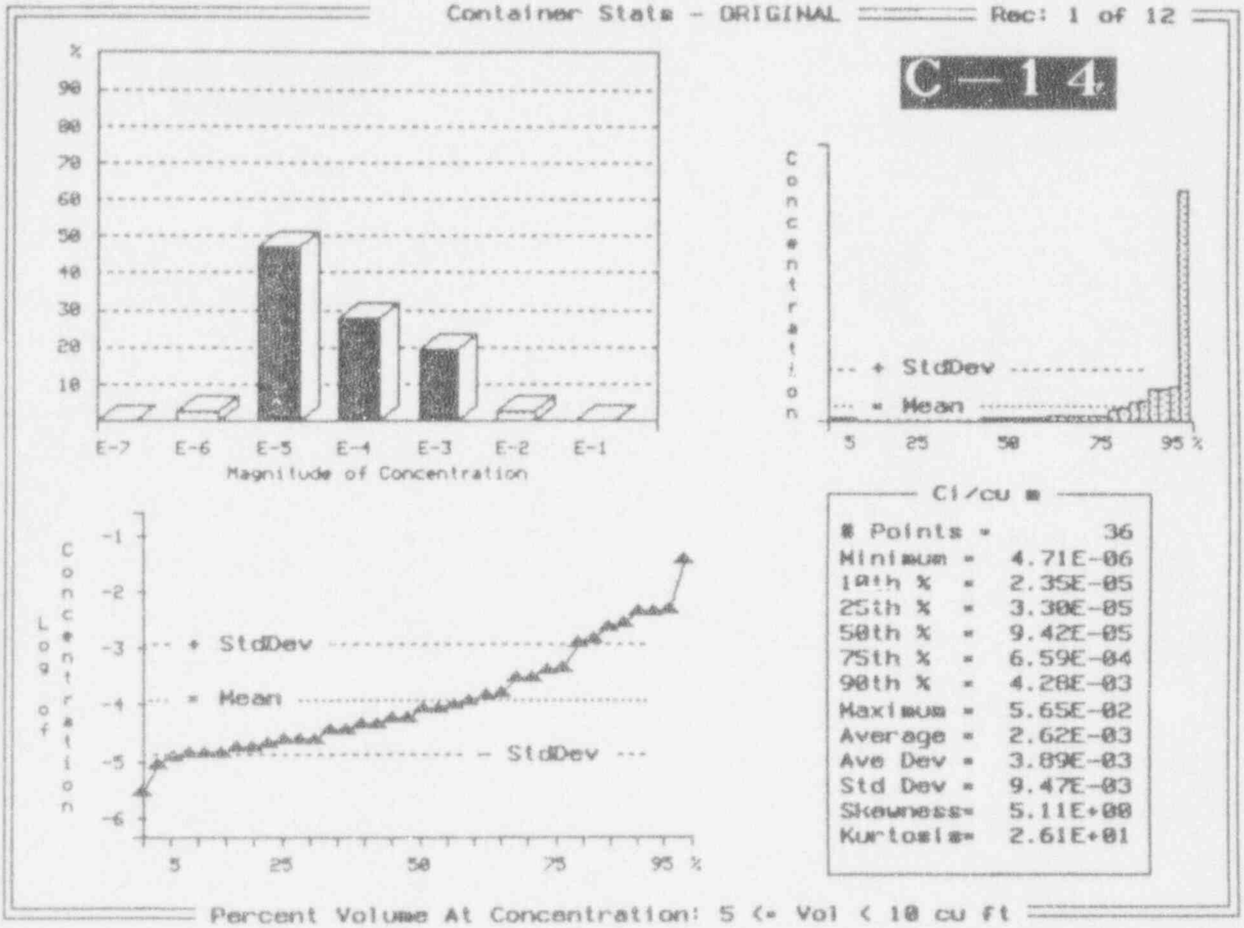

Exhibit 6-1 (Continued)

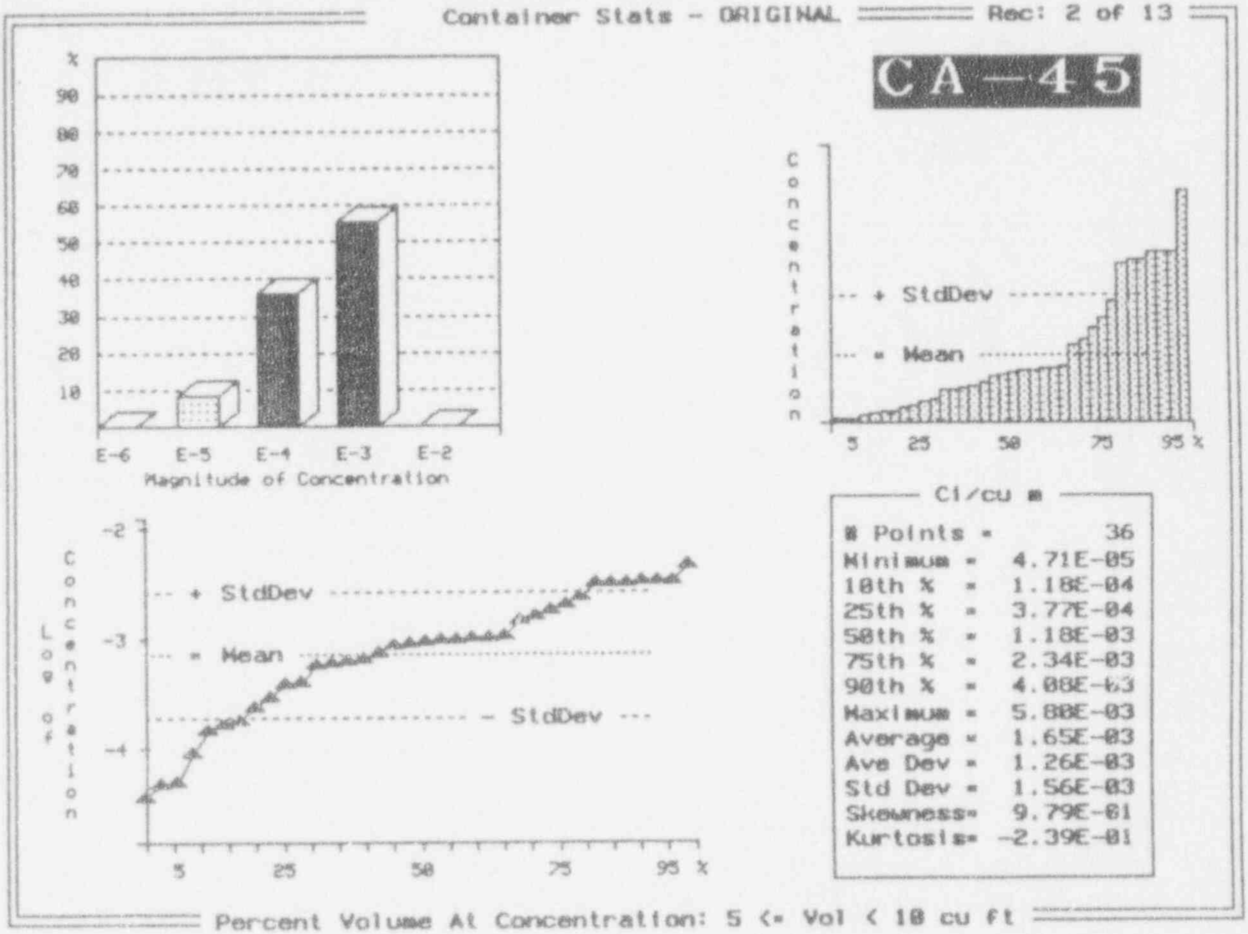

Exhibit 6-1 (Continued)

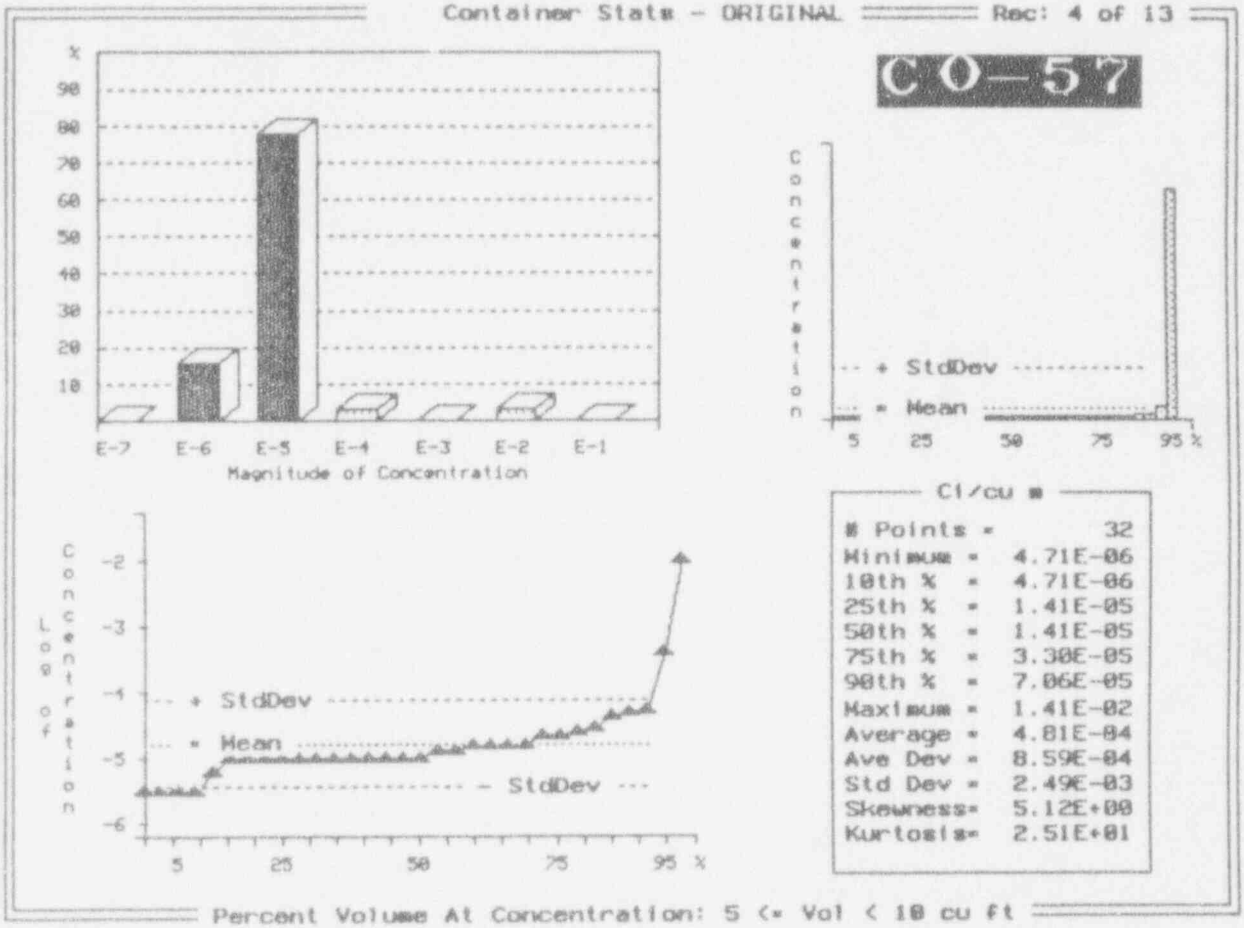

Exhibit 6-1 (Continued)

Container Stats - ORIGINAL — Rec: 7 of 18

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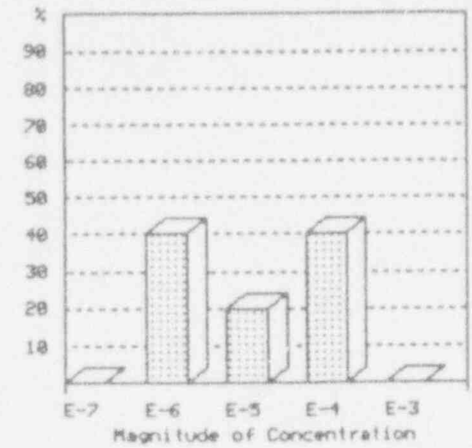
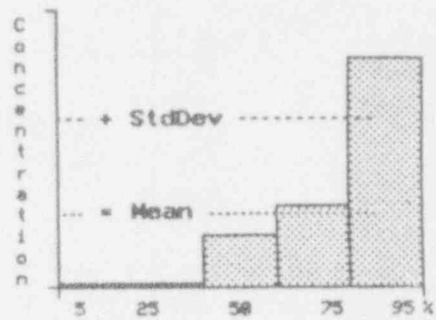
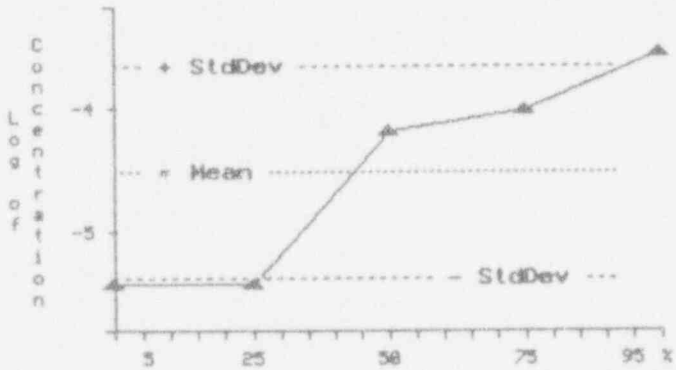






Ci/cu m	
# Points =	5
Minimum =	4.71E-06
10th % =	4.71E-06
25th % =	4.71E-06
50th % =	8.00E-05
75th % =	1.22E-04
90th % =	3.53E-04
Maximum =	3.53E-04
Average =	1.13E-04
Ave Dev =	9.98E-05
Std Dev =	1.43E-04
Skewness=	7.64E-01
Kurtosis=	-1.30E+00

Percent Volume At Concentration: 5 <= Vol < 10 cu ft

Table 6-5

Comparison of Selected Radionuclide Concentration Distributions in Container Level Medical Waste

	Radionuclide (pCi/g) - Percentile											
	H-3			I-125			Cr-51			C-14		
	1	50	99	1	50	99	1	50	99	1	50	99
Aggregate	1.4E-5	1.2E-2	1.6	9.4E-6	1.6E-3	1.4	4.7E-6	2.8E-3	4.4E-1	4.7E-6	9.4E-5	5.7E-2
Midwest												
Absorbed Aqueous Liquids	3.3E-5	1.2E-2	5.0E-1	2.8E-5	5.7E-3	5.0E-1	4.7E-6	2.8E-2	4.4E-1	4.7E-6	7.1E-5	5.7E-2
Animal Carcasses	1.4E-5	1.7E-2	6.0E-1	9.4E-6	1.9E-5	4.3E-3	4.7E-6	1.9E-5	2.6E-2	1.4E-4	1.4E-4	7.1E-3

The sorts provided in the above tables and in Appendices C and D describe the properties of wastes shipped directly (i.e., non-brokered) by generators to either Beatty or Richland from 1988 to 1990. Barnwell data are currently only available at the shipment level. Waste shipped by brokers or processors are also not included in the above analyses because the brokered data available at the container level are aggregated in a manner that precludes sorting by category of waste generators. Accordingly, brokered waste are addressed separately (see Section 8.0).

6.3.2 Waste Characterization - Shipment Level

A search of the database captured the following data at the shipment level for all direct shipments of Class A waste made 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/cm^3 average density
- 50.3 Ci of total activity, 0.04 Ci/m^3

Table 6-3 reveals that the total volume and radioactivity inventory of the shipments, both brokered and unbrokered, by medical waste generators from 1986 to 1990 was 3,682 cubic meters and 351 Ci, respectively. Accordingly, this search represents about 34 percent of the volume (the balance was shipped by brokers and possibly a very small portion is Class B waste and over 14 percent of the activity of the waste shipped for disposal. In addition, the average gross radionuclide concentration in the sort is about 0.04 Ci/m^3, while the average gross radionuclide concentration in all medical waste is about 0.1 Ci/m^3. These radionuclide concentration results are not consistent with the results of the container level analysis provided above, which has an average concentration of 0.14 Ci/m^3. This difference may be due, in part, to the nonrepresentative nature of the container level data.

This inconsistency might be due to various causes, e.g., one or more improperly coded shipments or containers in the database. For example, one possibility might involve a commingled shipment that includes a large number of Class A waste drums and one drum of Class B waste. In this case, the entire shipment might be simply categorized as Class A. Consequently, the higher levels of activity contained in the Class B drum would raise the overall radionuclide concentration. The database does not provide the means to identify or trace the source of such discrepancies.

Exhibit 6-2 presents the concentration distributions of the principal radionuclides contained in the shipments captured by the sort.

EXHIBIT 6-2

MEDICAL WASTE - SHIPMENT LEVEL ANALYSIS

Number of shipping records captured:	1,032
Number records with container data:	2*
Number of manifests captured:	0
Number of container records captured:	112
Number of isotope records captured:	4,282
Total activity of shipment (Ci):	5.03E+01
Total volume of shipments (m^3):	1.26E+03
Computed weight of shipments (kg):	9.73E+05
Total weight of containers (kg):	1.84E+04*
Nominal density (g/cm^3):	7.75E-01
Total density (g/cm^3):	7.74E-01*
Total concentration (Ci/m^3):	4.01E-02
Total concentration (pCi/g):	1.94E+05*

* For shipments with container data.

Exhibit 6-2 (Continued)

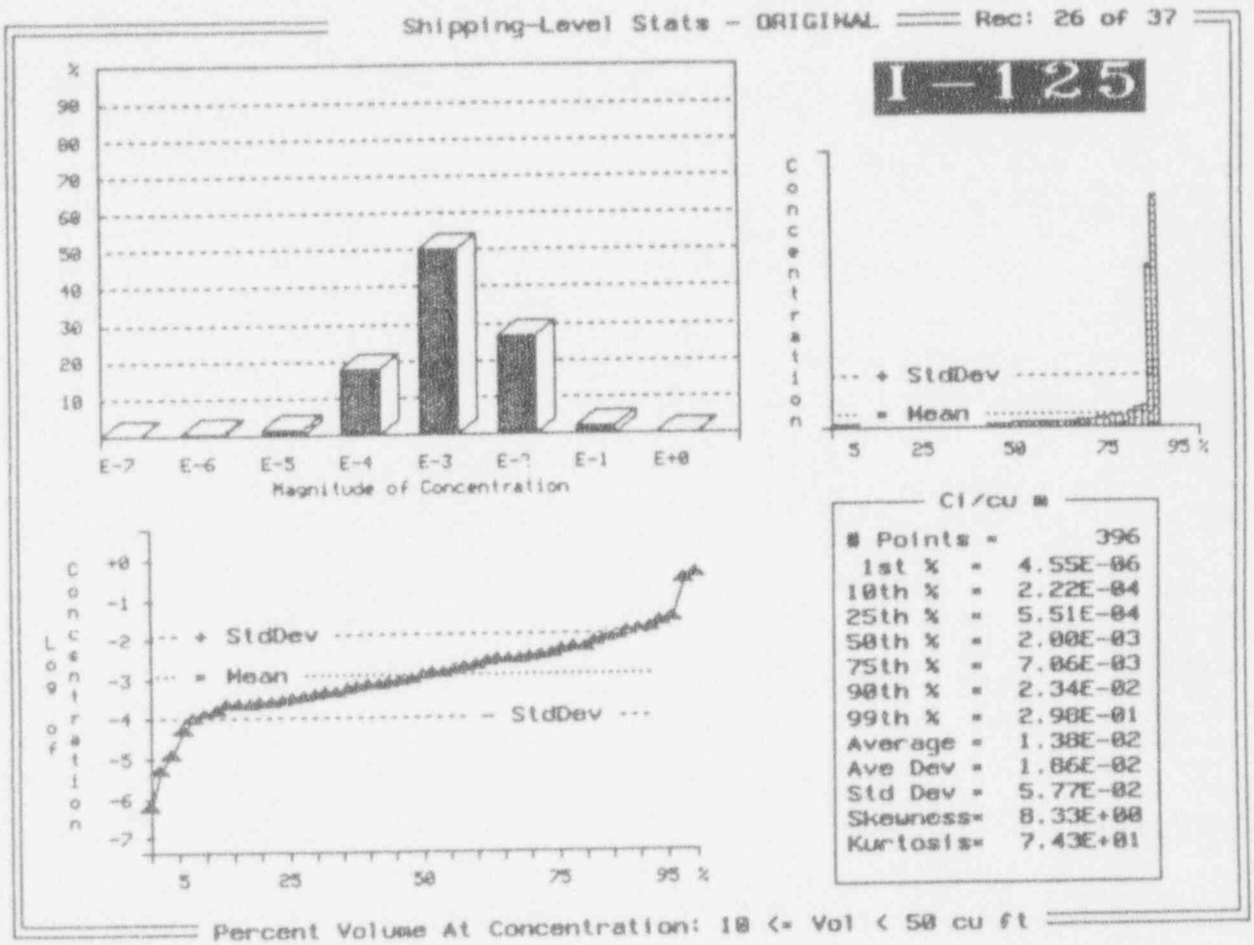


Exhibit 6-2 (Continued)

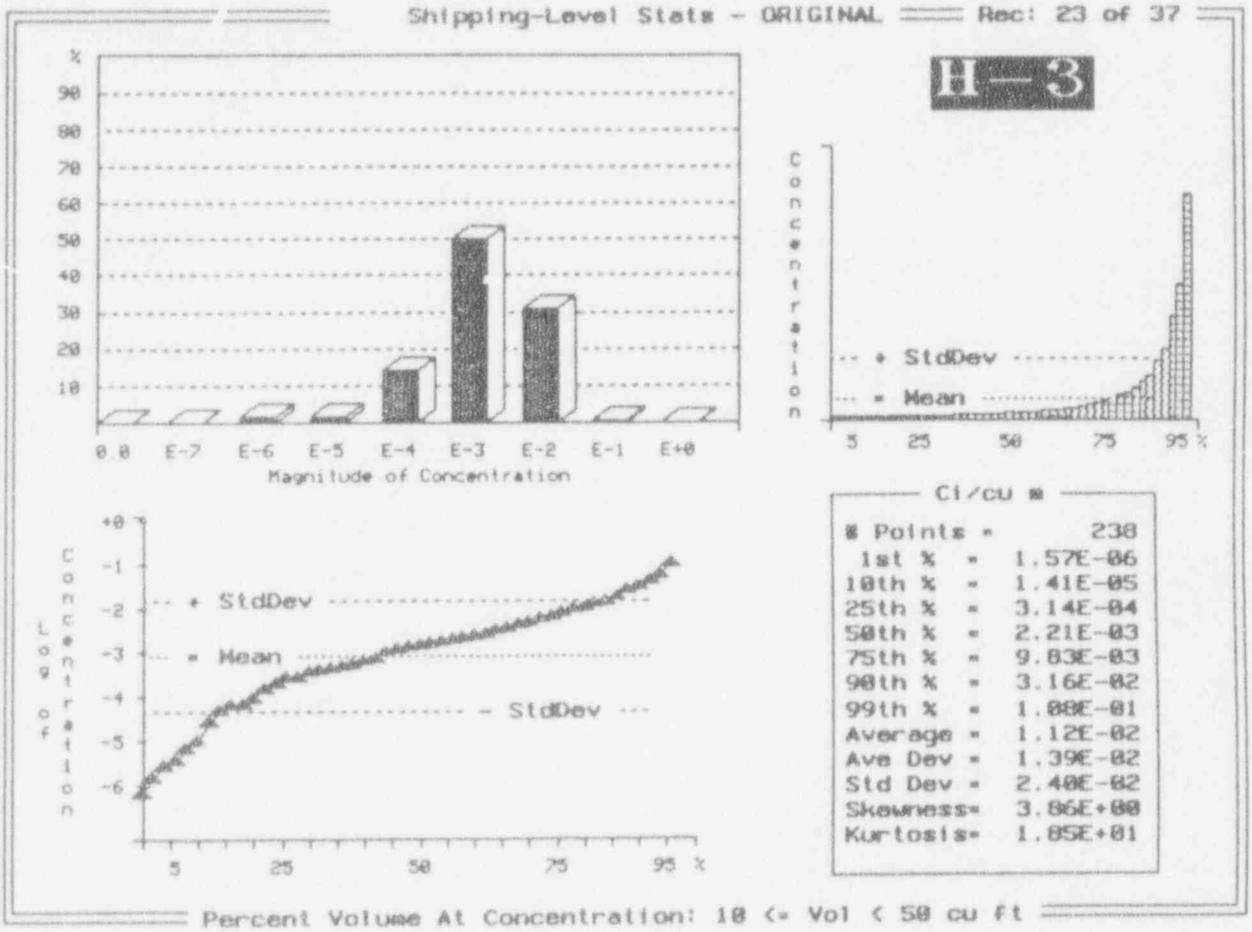


Exhibit 6-2 (Continued)

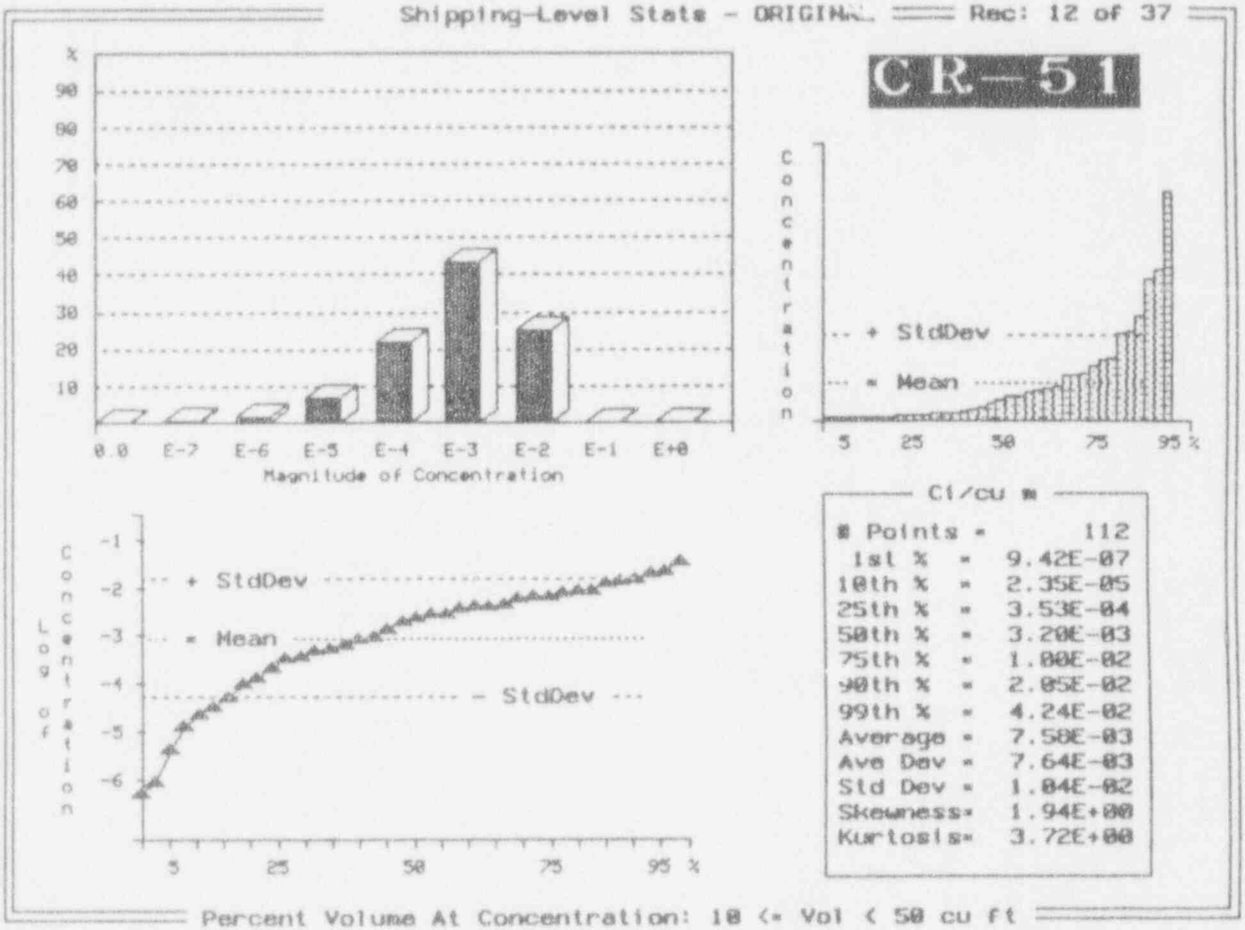


Exhibit 6-2 (Continued)

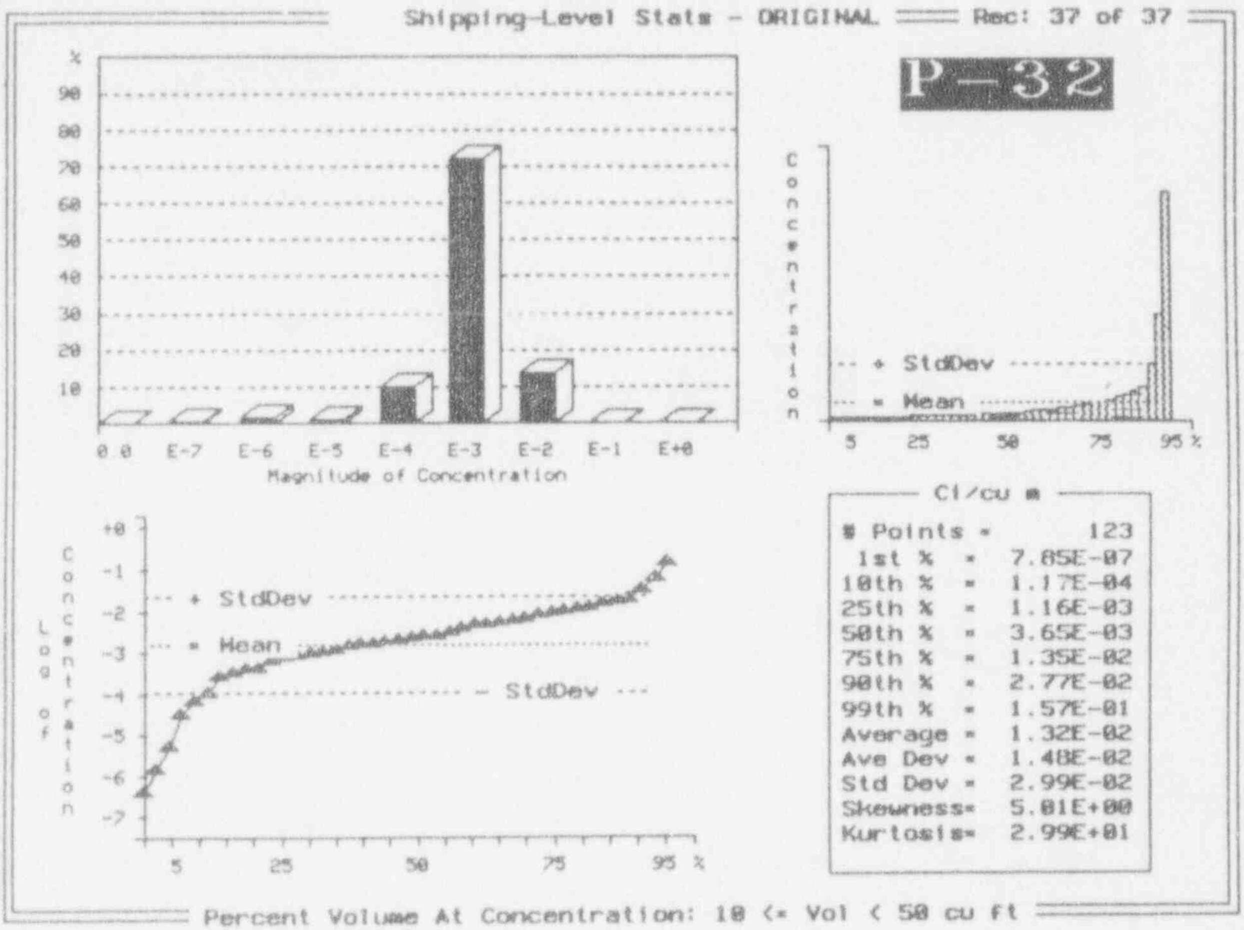


Exhibit 6-2 (Continued)

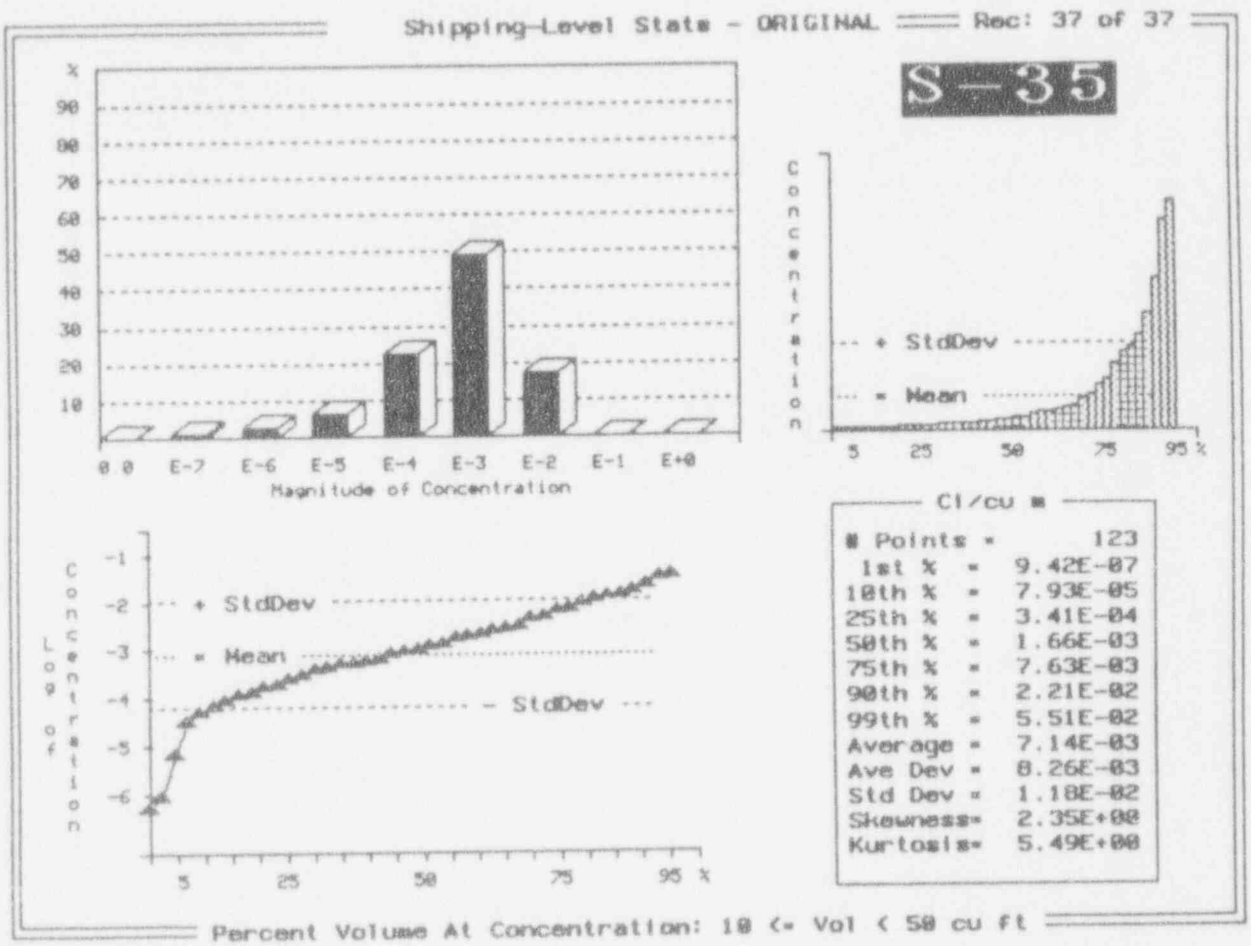


Exhibit 6-2 (Continued)

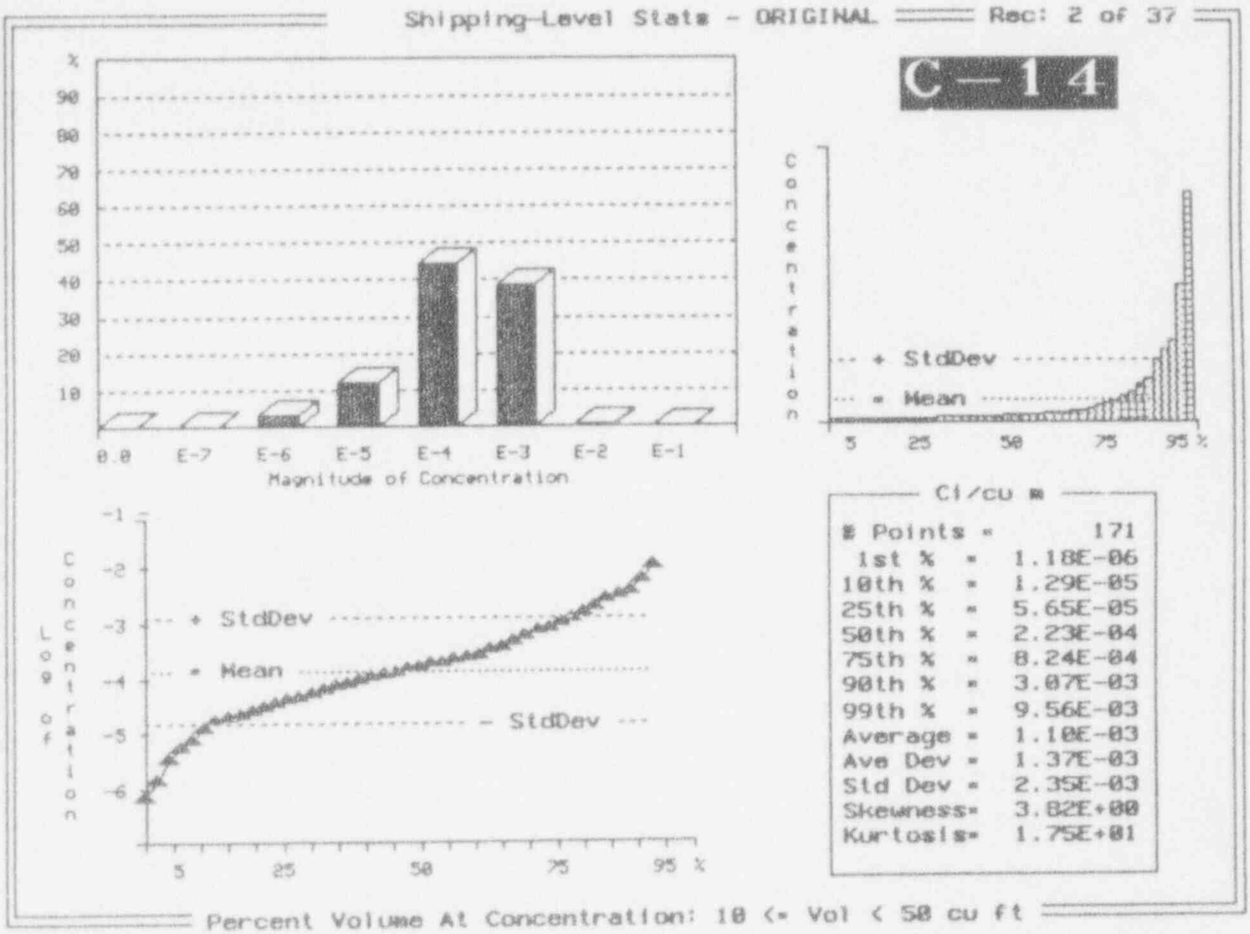


Exhibit 6-2 (Continued)

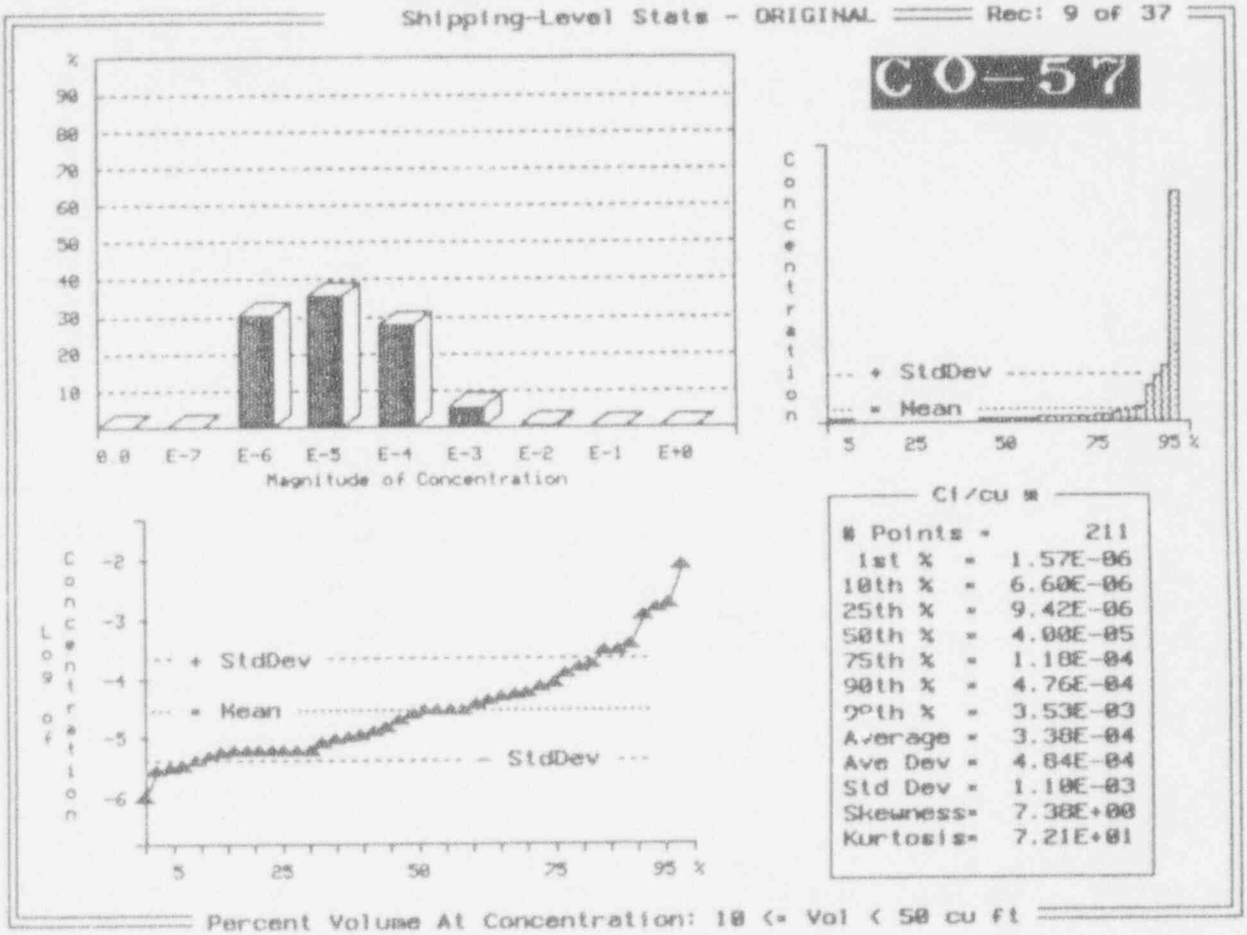


Exhibit 6-2 (Continued)

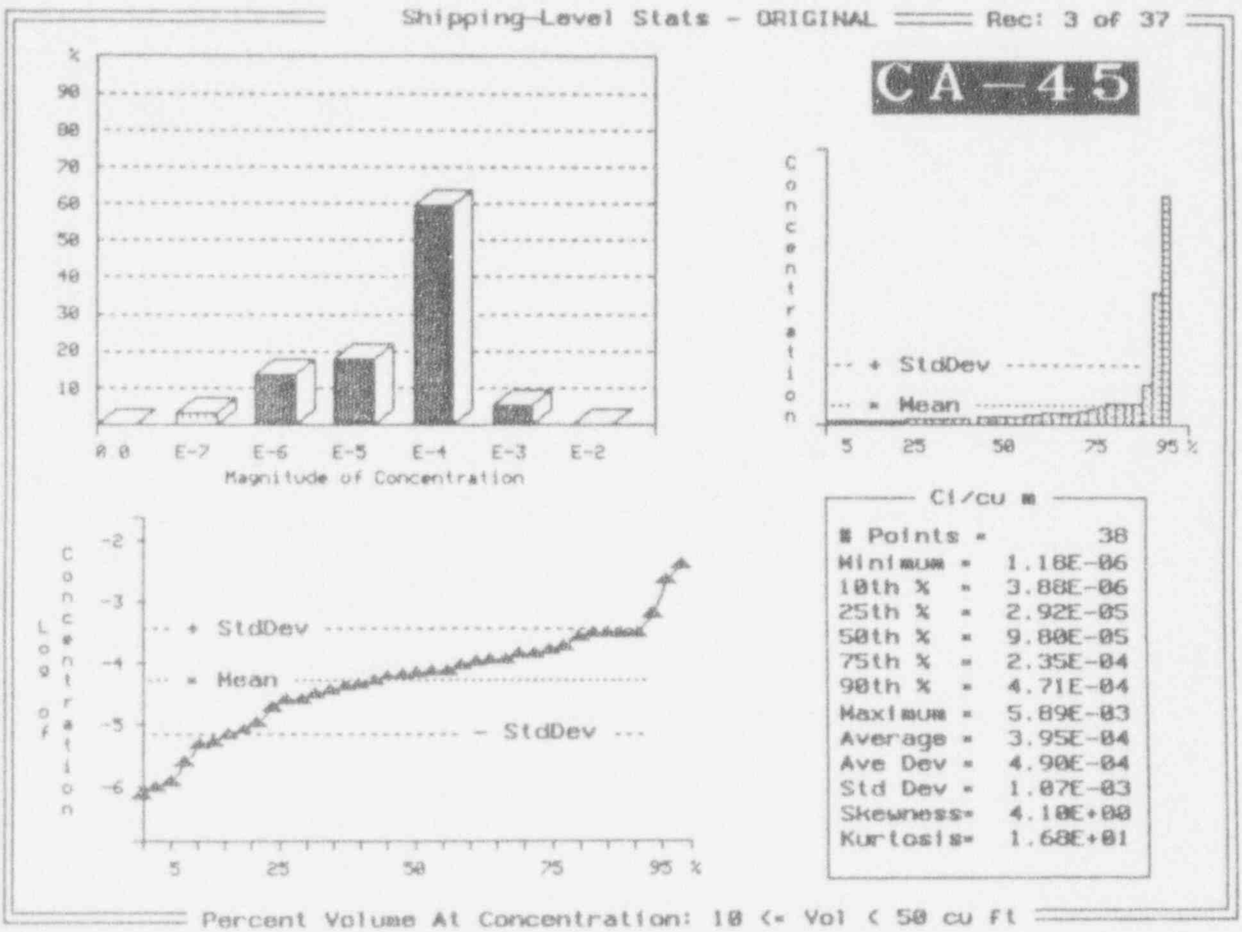
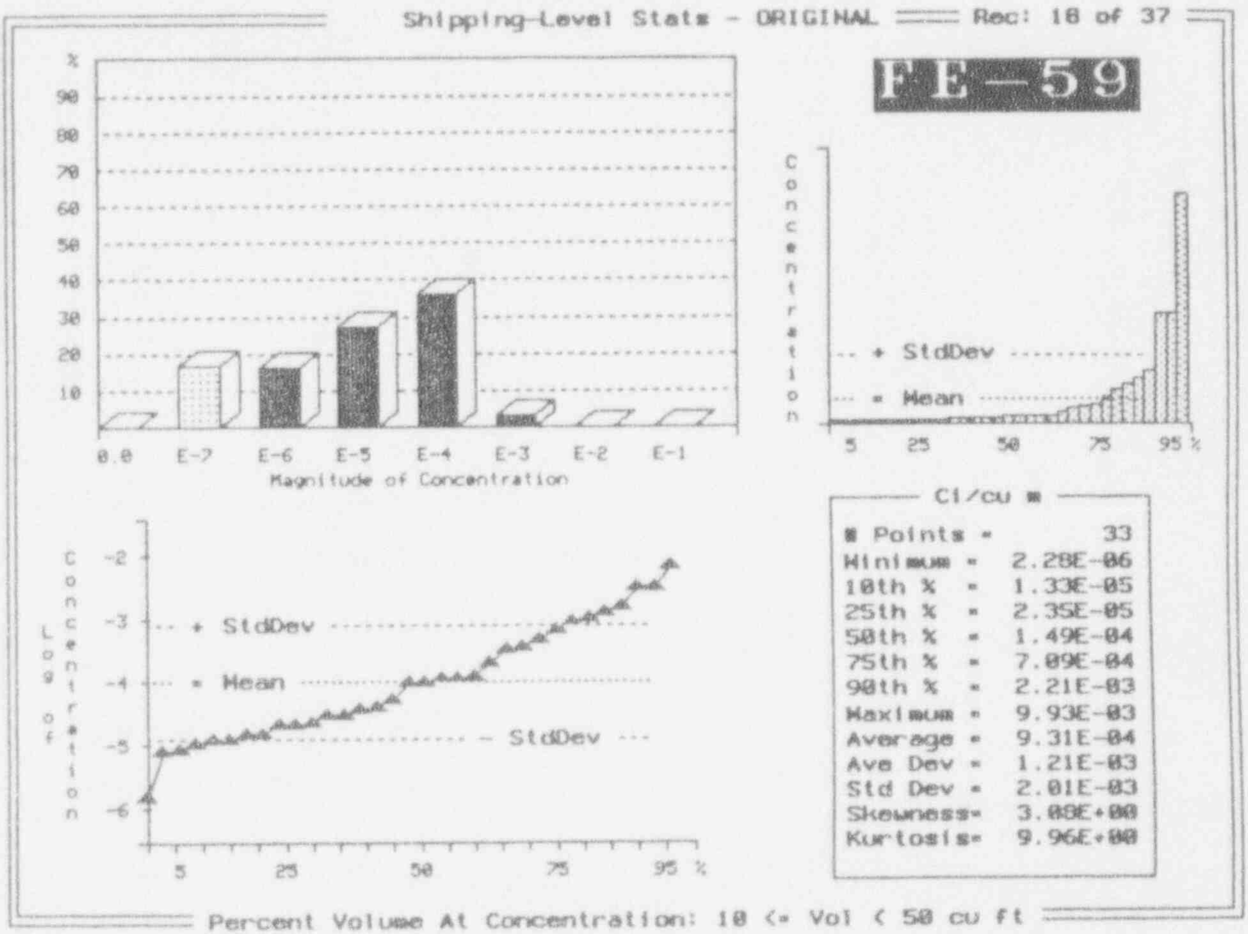


Exhibit 6-2 (Continued)



The sorts are grouped into the following categories of shipment sizes:

- <10 cubic feet per shipment
- 10 to 50 cubic feet per shipment
- 50 to 100 cubic feet per shipment
- 100 to 500 cubic feet per shipment
- 500 to 1,000 cubic feet per shipment

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides present in 10 to 50 cubic feet shipments, which contain the majority of the waste by volume and activity:

Radionuclide	10CFR61 Class A Limits (Ci/m^3)	Total Activity Captured (Ci)	Concentration (Ci/m3) Median	Average	1%ile or min.	10%ile	90%ile	99%ile or max.
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
	Total	4.59E+01						

Though the sort captured 85 radionuclides, the above nuclides constitute 45.9 of the 50.3 Curies (or 91%) captured by the sort. The shipment-level data were also sorted according to Compact and unaffiliated State to determine the degree to which the radionuclide concentration distributions vary regionally. The detailed results of these sorts are shown in Appendix E. Table 6-6 presents a summary of these results for some of the key radionuclides.

The results reveal that at all percentile levels, the aggregate radionuclide concentrations at the container and shipment level agree within a factor of two to ten. This implies that, though the container level data are a very small fraction of the total medical waste (i.e., about 1%), the values are in fairly close agreement with the more representative shipment level data. The results also indicate that the variability of the radionuclide concentrations within a given region and radionuclide is large as compared to the variability among regions. Accordingly, it appears that radionuclide concentrations among regions do not differ significantly.

Table 6-6

Comparison of Selected Radionuclide Concentration Distributions at the Shipment Level for Medical Waste Generators (1986 to 1990)

	Total Volume (m3)	Volume Captured (m3)	I-125			H-3			Cr-51			P-32		
			Radionuclide (Ci/m3) - Percentile											
			1	50	99	1	50	99	1	50	99	1	50	99
Aggregate Container Level			9.4E-6	1.6E-3	1.4	1.4E-5	1.2E-2	1.6	4.7E-6	2.8E-3	4.4E-1	4.7E-6	1.4E-3	6.9E-2
Aggregate Shipment Level			4.7E-6	2.0E-3	3.0E-1	1.6E-6	2.2E-3	1.1E-1	9.4E-7	3.2E-3	4.2E-2	7.9E-7	3.7E-3	1.6E-1
Shipment Level By Region														
Northwest	103	38.6	4.7E-4	9.4E-4	4.9E-2	1.2E-4	4.3E-3	3.2E-2	3.9E-5	3.9E-5	9.0E-5	9.4E-6	4.7E-4	3.5E-3
Midwest	438	157.4	8.7E-3	8.8E-3	1.0E-2	6.0E-3	2.0E-2	2.1E-2	1.0E-2	1.1E-2	1.5E-2	4.7E-3	5.6E-3	5.8E-3
Central Midwest	177	1.8	4.7E-4	4.7E-4	5.5E-4									
Southeast	59.1	17.8	1.3E-3	2.2E-3	3.2E-3	1.6E-3	2.5E-3	3.3E-3	6.5E-3	1.3E-2	2.0E-2			
Northeast	461	131.1	8.8E-6	8.8E-4	9.7E-3	1.4E-5	7.5E-4	1.8E-2	1.6E-6	2.3E-5	1.6E-4	1.2E-4	1.5E-3	3.3E-2
Appalachian	360	122.8	4.6E-6	8.1E-4	7.5E-2	1.6E-6	7.9E-4	8.1E-2	2.3E-6	1.1E-3	4.2E-2	1.9E-5	1.1E-2	2.2E-2
Southwest	805	241.8	1.2E-6	2.4E-4	4.6E-2	3.1E-5	1.9E-3	1.8E-1	3.6E-7	5.4E-4	2.1E-2			
District of Columbia	25.8	2.1	Only One Shipping Record											
Massachusetts	130	34.3	8.8E-4	3.0E-3	3.7E-3	6.1E-5	8.4E-4	5.8E-3	5.9E-5	7.0E-4	2.3E-3	2.9E-3	1.3E-2	3.8E-2
New York	1240	495.2	9.4E-6	3.4E-3	1.2E-1	1.2E-6	3.5E-3	8.0E-2	9.4E-7	3.9E-3	5.2E-2	7.9E-7	3.1E-3	2.4E-1
Rhode Island	116	12.2	2.4E-5	1.2E-3	9.9E-2	1.0E-5	1.2E-3	2.2E-2	4.7E-5	6.3E-4	1.2E-2	1.2E-4	8.5E-3	1.6E-1
Vermont	0.5	0.4	Only One Shipping Record											

These results are also complemented with histograms and cumulative distribution curves shown in Appendix F. Radionuclide histograms and cumulative distributions are presented only for those nuclides that are consistently being reported by waste generators. Appendix F also includes summary sheets that provide additional information for each Compact region and State, including the associated number of waste generators, total number of shipping records and containers (as is applicable), shipment weights, and total and fractional waste volumes and activity levels.

The data provided in Appendix F reveals that, for some waste forms and most nuclides, radionuclide concentrations tend to cluster over a narrower range, typically from about 10^2 to 10^5 pCi/g for both shipment and container level data. In instances, where concentrations are significantly higher, the results again tend to parallel each other at the container and shipping levels.

On the low end, a few clusters of concentrations are confined to a narrower range from about 0.1 to 10^2 pCi/g. This feature is typical of the analyses performed at the shipment level. On the other hand, analyses performed at the container level revealed concentrations starting at a higher range, typically from about one to 10^2 pCi/g. These features reveal the impact of determining radionuclide concentrations by averaging the total activity over the entire shipment volume.

6.4 Mixed Waste

Mixed waste, characterized by both hazardous chemical and radioactive properties, are generated during various activities when chemicals are introduced as cleaning agents or solvents. Activities that may result in the generation of mixed waste include R&D, laboratory analyses, and decontamination activities. Actual generation rates are highly variable and are dependent upon specific facility practices.

Mixed waste generation rate estimates are based on the results of the National Profile on Commercially-Generated Low-Level Radioactive Mixed Waste (NUREG/CR-5938), as such waste is not being shipped to the disposal sites (NRC92). Consequently, the low-level database does not contain such information. The generation rates were weighted on a national basis to account for facilities which did not respond to the survey and those that were not queried during the survey (NRC92).

Tables 6-7 and 6-8 summarize the results of the 1990 National Profile for medical waste generators. The results indicate that spent scintillation fluids make up about 95 percent of the waste volume, see Table 6-7.

Table 6-7 Medical Generators Mixed Waste Profile - 1990 [a]

Waste Stream	Weighted Annual Generation Rate (ft^3/yr)	Percent
Liquid Scintillation Fluids	18,862	94.8
Waste Oils	(b)	--
Chlorinated Organics	269	1.4
Chlorinated Fluorocarbons	(b)	--
Other Organics	676	3.4
Metals (Pb and Hg)	68	0.3
Corrosive Materials	2	0.01
Other Materials	27	0.1
Total	19,904	(b)

(a) Data extracted from NUREG/CR-5938, Table 4-6 (NRC92).
(b) Result may not add up to 100% due to rounding off.

Table 6-8 summarizes the results of the 1990 National Profile by Compact regions and States. The results indicate that five Compacts and two States generate about 87 percent of the waste volume. In decreasing order, they are the Southwest and Southeast Compacts, the State of Texas, the Central Midwest Compact, New York State, and the Northwest and Northeast Compacts. The 1990 mixed waste volume for all regions has been estimated to be 19,904 ft^3 in 1990 (NRC92).

Table 6-8 Medical Facilities - 1990 Regional Mixed Waste Generation Profile[a]

Compact/State	Estimated Volume (ft^3)
Northwest	1,271
Rocky Mountain	(b)
Central States	74
Midwest	716
Central Midwest	2,208
Southeast	4,061
Northeast	1,168
Appalachian	854
Southwest	4,146
Maine	(b)
Massachusetts	911
New York	1,829
Texas	2,661
Vermont	(b)
New Hampshire	(b)
Rhode Island	(b)
District of Columbia	5
Puerto Rico	(b)
Total	19,904

(a) Data extracted from NUREG/CR-5938, Table 4-10 (NRC92).
(b) No data reported or facilities were not surveyed.

6.5 Medical Waste Generators - Class A Waste Description and Characteristics of Typical Medical Waste Generators

The purpose of this section is to identify waste streams and forms, volumes, and radionuclide distributions representative of typical medical waste generators. In order to present the results in terms of the volume and activity shipped per waste generator, it was necessary to estimate the number of waste generators using the number of unique waste generator identification codes assigned by the disposal sites.

The number of unique generator codes represents all of the waste generators that ever shipped waste from 1986 to late 1990, and does not necessarily reflect the current population size. In addition, it is not uncommon for some waste generators to have access to two disposal sites. In such instances, a single generator would have two identification codes, thereby overestimating the number of waste generators and underestimating the volume and activity of waste shipped per waste generator. It was not possible to estimate the extent of such practices since waste generators cannot be identified by name from the database.

6.5.1 Waste Streams and Forms

The following Class A waste streams are representative of the medical sector:

- dry solids,
- compacted and non-compacted dry active waste,
- animal carcasses and other types of biological waste,
- aqueous and non-aqueous waste in vials and sorbents,
- solidified liquids (solvents and other non-aqueous liquids), and
- non-cartridge filter media.

These waste streams are routinely produced by the majority of generators, make up a large fraction of the total waste volume, and can be relatively well characterized for their radiological and physical properties.

6.5.2 Waste Volume

Tables 6-9 and 6-10 present averages, ranges, Class A waste generation volumes, and total number of waste generator identification codes by Compact regions or States. The data characterize overall practices from 1986 to 1990. For example, the average medical waste generator located in the Northwest Compact produced 4.9 m^3 of waste over a five year period, from 1986 to 1990.

Table 6-9 Waste Volume Distribution Among Medical Generators by Compact Regions and States[a]

Compact/State	No. of Unique Gen. Code	-- Waste Volume - m^3 Five-Year Total Vol. All Gen.	Ave. Gen. Five-Year Total Vol.	Ave. Gen. Yearly Volume --
Northwest	21	103	4.9	1.0
Rocky Mountain	16	9.9	0.6	0.1
Central	16	9.0	0.6	0.1
Midwest	91	437	4.8	1.0
Central Midwest	50	177	3.5	0.7
Southeast	46	58	1.0	0.2
Northeast	56	461	8.2	1.7
Appalachian	72	360	5.0	1.0
Southwest	102	804	7.9	1.6
District of Columbia	11	26	2.4	0.5
Maine	1	0.2	0.04	<0.01
Massachusetts	35	128	3.7	0.7
New Hampshire	2	0.15	0.08	0.01
New York	166	1,238	7.5	1.5
Puerto Rico(c)	---	---	---	---
Rhode Island	9	116	12.9	2.6
Texas	19	45	2.4	0.5
Vermont	1	0.5	0.3	0.05
Total:	714	3,973	66	13.3
- Low:	1	0.5	0.04	0.01
- High:	166	1,238	12.9	2.6
- Average:	42	234	3.9	0.78
- Std. Dev.:	45	341	3.6	0.74

(a) Compiled from data given in Appendix F for all Class A waste forms.
(b) Aggregate and yearly average waste generation rates are rounded off. See text for details. To convert volume to to cubic feet, multiply cubic meter by 35.3.
(c) No waste disposed of during the reported period.

Table 6-10 Medical Waste Volume Distributions Among Compact Regions and States[a]

Compact/State	Waste Volume (m^3) per Waste Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	1.98E-03	6.36E-01	2.91E+01
Rocky Mountain	3.68E-03	3.06E-02	3.84E+00
Central	1.53E-02	1.22E-01	3.81E+00
Midwest	5.66E-04	1.96E-01	2.96E+02
Central Midwest	1.33E-02	3.53E-01	3.71E+01
Southeast	5.66E-04	9.34E-02	1.76E+01
Northeast	1.53E-02	3.96E-01	1.30E+02
Appalachian	5.66E-04	5.12E-01	9.33E+01
Southwest	5.66E-04	5.10E-01	1.05E+02
District of Columbia	1.11E-01	8.10E-01	1.25E+01
Maine	2.12E-01	2.12E-01	2.12E-01
Massachusetts	1.53E-02	7.92E-01	4.14E+01
New Hampshire	7.59E-02	7.59E-02	7.65E-02
New York	1.90E-02	6.22E-01	1.41E+02
Puerto Rico(c)	---	---	---
Rhode Island	1.13E-01	5.43E+00	4.72E+01
Texas	9.06E-03	2.62E-01	3.25E+01
Vermont	7.08E-02	7.08E-02	4.25E-01

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. See text for details.
(b) Yearly waste generation distributions may be approximated by dividing above values by five. 1 m^3 = 35.3 cubic feet.
(c) No waste disposed of during the reported period.

The yearly average waste generation rate is derived by dividing the tabulated waste volume by five, or about 1.0 m^3 per year per waste generator for this example.

Table 6-10 indicates that, in the Northwest Compact, the waste volume per waste generator from 1986 to 1989 varies over four orders of magnitude, from 0.00198 to 29.1 m^3. At the 50th percentile, the aggregate volume is 0.636 m^3 per waste generator, yielding a yearly average of 0.13 m^3. Similar case comparisons can be made for other Compact regions or States. As can be noted, waste volumes vary significantly from year to year among generators as well as among Compact regions. For more details on waste volume distributions, refer to Appendix F.

6.5.3 Radionuclide Distributions and Concentrations

Total waste activity distributions are shown in Table 6-11. As can be noted, waste activity levels disposed per waste generator vary significantly among Compact regions and States. Over the period from 1986 to 1990, the total radionuclide content of the waste varied over seven orders of magnitude, from 1 uCi to 69.2 Ci per waste generator. At the 50th percentile, aggregate waste activities are relatively more stable, spanning three orders of magnitude across all regions. Appendix F presents a more detailed information on waste activity distributions.

The radionuclides most often cited by medical waste generators include C-14, H-3, Na-22, P-32, P-33, S-35, Cl-36, Ca-45, Sc-46, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ge-68, Ga-68, Se-75, Sr-85, Sr-90, Nb-95, Tc-99, Ru-103, In-111, Sn-113, In-114m, I-125, I-131, Cs-137, Cs-134, I-131, Ce-141, Gd-153, Tl-201, Po-210, Ra-226, Th-232, and U-238.

6.6 Geographic Distribution and Demographics of Medical Waste Generators

6.6.1 Geographical Distribution

Medical waste generators are located in both urban and rural areas. In most instances, medical waste generators are associated with large hospital and medical centers. Other medical waste generators, however, are situated near hospitals and medical centers, as they provide related support services, e.g., as with clinical labs. In general, there are no specific reasons for the location of such facilities, other than fulfilling regional health care services. In most instances, the establishment of the larger medical facilities, as institutions, pre-dates the use of radioactive materials in medical treatment.

Table 6-11 Medical Waste Activity Distributions Among Compact Regions and States[a]

Compact/State	Waste Activity (Ci) at Percentile[b] per Waste Generator (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	1.40E-05	2.97E-02	7.71E-01
Rocky Mountain	1.00E-06	8.66E-03	2.56E-01
Central	1.00E-06	1.00E-01	7.25E-01
Midwest	3.20E-05	1.00E-02	6.92E+01
Central Midwest	2.61E-04	1.00E-02	2.89E+00
Southeast	1.60E-05	1.75E-02	7.70E-01
Northeast	1.00E-06	1.55E-02	1.48E+01
Appalachian	7.90E-05	1.80E-02	4.39E+00
Southwest	8.35E-04	1.80E-02	1.20E+01
District of Columbia	5.00E-06	7.99E-04	6.26E-01
Maine	3.60E-01	3.60E-01	3.60E-01
Massachusetts	6.45E-04	3.41E-02	7.37E+00
New Hampshire	0.00E-00	0.00E-00	2.50E-01
New York	4.20E-05	8.06E-03	3.43E+00
Puerto Rico(c)	---	---	---
Rhode Island	2.05E-03	7.44E-02	1.29E+00
Texas	4.98E-04	4.80E-02	4.17E+00
Vermont	0.00E-00	0.00E-00	1.08E-02

(a) Compiled from data shown in Appendix F - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. Entries with 0.00E-00 values indicate that the database did not have any data for those records. See text for details.
(b) Yearly waste activity distributions may be approximated by dividing above values by five. 1 Ci = 3.7×10^{10} Bq.
(c) No waste disposed of during the reported period.

The locations of the major medical waste generators are identified by city, county, and state (see Appendix G-1). Medical waste generators may have more than one location identified under the same NRC and Agreement State license. However, it does not follow that all identified locations necessarily generate waste. The locations contained in Appendix G-1 were extracted from periodic reports issued by Compacts and States. Some states, however, did not provide this information since some generators and/or states have deemed this type of data to be confidential.

6.6.2 Demographics

Population data were obtained from the Bureau of Census based on the 1990 census results (DOC92). The data were sorted to tally population counts by Compact, State, and county, when identified. Population data were compiled for each of the nine Compacts and nine unaffiliated States (see Appendix G-2).

7.0 NUCLEAR POWER PLANTS

7.1 Introduction

By the end of 1990, there were 111 nuclear power plants operating in the United States, representing a total electrical capacity of 99,559 megawatts and supplying nearly 20% of the nation's electrical needs (ANS91). Pressurized-water reactor (PWR) designs are more prevalent than boiling-water reactors (BWR); i.e., 74 PWRs versus 37 BWRs. Electrical power ratings vary from 67 to 1,250 net MWe per unit, with most reactors falling within the range of 800 to 1,150 net MWe. In 1990, reactor capacity factors ranged from about 20 to 100% with an overall average of 68 percent (NRC91).

A list of commercially operating plants is given in Table 7-1. Power plants are operated in single or multiple reactor units at 69 sites located in 33 states. There are 30 sites with two reactor units and six with three units. The remaining sites (33) consist of a single reactor unit. Since 1964, a total of 14 nuclear power plants were taken out of operation because of technical, regulatory, and economic considerations, accidents, or due to public opposition. Plants that were taken out of service or never placed in commercial operation include six BWRs, four PWRs, and four gas- and metal-cooled reactors.

This chapter is structured differently than the previous chapters due to the relatively unique nature of the waste and the level of detail of the information characterizing low-level waste from nuclear power plants. Unlike the other categories of waste generators, most, and in some cases all, of the nuclear power plant waste is shipped directly to the disposal sites (i.e., unbrokered). Additional information is also available from various studies. Section 8.0, Table 8-3 presents an aggregate breakdown of waste volumes and activity levels handled by waste brokers or processors for power plants.

In reviewing the information provided in this section, the reader is cautioned that the database incorporates some inherent limitations that should be recognized before reaching any conclusions. Some of these limitations are associated with generation and disposal practices, while others are due to differences in how the data are coded by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

Table 7-1 Nuclear Power Plants in Commercial Operation[a]

State and Compact Region[b]	Plant Name	No. of Units	Type	Net MWe
Alabama/SE	Browns Ferry	3	BWR	1065
	J.M. Farley	2	PWR	828
Arizona/SW	Palo Verde	3	PWR	1221
Arkansas/CE	Arkansas One	2	PWR	858
California/SW	Diablo Canyon	2	PWR	1087
	San Onofre	3	PWR	1080/436
Connecticut/NE	Haddam Neck	1	PWR	565
	Millstone-1	1	BWR	654
	Millstone-2/3	2	PWR	863/1142
Florida/SE	Crystal River	1	PWR	821
	St. Lucie	2	PWR	839
	Turkey Point	2	PWR	666
Georgia/SE	E.I. Hatch	2	BWR	766
	A.W. Vogtle	2	PWR	1100
Illinois/CM	Byron	2	PWR	1105
	Clinton	1	BWR	930
	Dresden-2/3	2	BWR	773
	Lasalle	2	BWR	1036
	Quad Cities	2	BWR	769
	Zion	2	PWR	1040
	Braidwood	2	PWR	1120
Iowa/MW	Duane Arnold	1	BWR	538
Kansas/CE	Wolf Creek	1	PWR	1135
Louisiana/CE	River Bend	1	BWR	936
	Waterford	1	PWR	1075
Maine/Unf.	Maine Yankee	1	PWR	830
Maryland/AP	Calvert Cliffs	2	PWR	825
Massachusetts/Unf.	Pilgrim	1	BWR	670
	Atomic Yankee	1	PWR	167
Michigan/MW	Big Rock Point	1	BWR	67
	D.C.Cook	2	PWR	1060
	Fermi	1	BWR	1075
	Palisades	1	PWR	768
Minnesota/MW	Monticello	1	BWR	536
	Prairie Island	2	PWR	503
Mississippi/SE	Grand Gulf	1	BWR	1142
Missouri/MW	Callaway	1	PWR	1125
Nebraska/CE	Cooper	1	BWR	764
	Fort Calhoun	1	PWR	478
New Jersey/NE	Hope Creek	1	BWR	1031
	Oyster Creek	1	BWR	620
	Salem	2	PWR	1106

Table 7-1 Nuclear Power Plants in Commercial Operation[a], Cont'd

State and Compact Region[b]	Plant Name	No. of Units	Type	Net MWe
New Hampshire/Unf.	Seabrook	1	PWR	1150
New York/Unf.	J.A. Fitzpatrick	1	BWR	757
	R.E. Ginna	1	PWR	470
	Indian Point-2/3	2	PWR	970
	Nine Mile Point	2	BWR	610/1072
North Carolina/SE	Brunswick	2	BWR	790
	McGuire	2	PWR	1129
	Shearon Harris	1	PWR	860
Ohio/MW	Davis Besse	1	PWR	874
	Perry	1	BWR	1141
Oregon/NW	Trojan	1	PWR	1095
Pennsylvania/AP	Beaver Valley	2	PWR	810/833
	Limerick	2	BWR	1055
	Peach Bottom-2/3	2	BWR	1035/1051
	Susquehanna	2	BWR	1038
	Three Mile Island	1	PWR	808
South Carolina/SE	Catawba	2	PWR	1129
	Oconee	3	PWR	846
	Robinson	1	PWR	665
	V.C. Summer	1	PWR	885
Tennessee/SE	Sequoyah	2	PWR	1148
Texas/Unf.	South Texas Project	2	PWR	1250
	Comanche Peak	1	PWR	1150
Vermont/Unf.	Vermont Yankee	1	BWR	504
Virginia/SE	North Anna	2	PWR	915
	Surry	2	PWR	781
Washington/NW	Washington Project	1	BWR	1095
Wisconsin/MW	Kewaunee	1	PWR	503
	Point Beach	2	PWR	485

(a) Commercially operating plants by the end of 1990 (ANS91).
(b) Key to low-level waste Compact regions: NW, Northwest,; MW, Midwest; NE, Northeast; AP, Appalachian; CE, Central Interstate; CM, Central Midwest; SE, Southeast; SW, Southwestern; and Unf., unaffiliated State.

7.2 Characterization of Nuclear Power Plant Waste Generation Activities

Nuclear power plant waste and generation rates are well characterized[3] (DOE90a, DOE90b, EGG90, EPR84, EPR88, NRC81b, NRC82, NRC87, NRC90, NRC92). 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, such as 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 dry active and dry solid waste. Wet waste streams include spent resins, sludge, filters, and evaporator bottoms generated while maintaining plant coolant purity and chemistry levels within limits. During plant outages, dry active, solid materials, and equipment tend to be the more prevalent types of waste. The generation of dry waste is usually associated with various maintenance activities that involve a large work force, require access into all plant areas, and include accessing contaminated plant systems and components.

Studies conducted by the Electric Power Research Institute (EPRI) indicate that there is no single parameter that best defines waste generation rates, e.g., electrical capacity (EPR84). Rather, it was noted that several factors govern waste generation rates. Such factors include outage duration, number of plant personnel, type of maintenance or outage, etc. For PWRs, the parameters that seem to best correlate with dry waste generation rates are the number of personnel involved in an outage and radiation exposures. For BWRs, dry waste generation rates appear to be dependent upon outage durations. On the other hand, wet waste generation rates at both BWRs and PWRs seem to correlate with dry waste generation.

It should be noted that waste generation rates are also dependent upon reactor design and site features. Such features include plant vintage and number of operating years, fresh versus salt water cooling, and deep-bed versus filter and demineralizer

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[3] Nuclear Management and Resources Council, Inc., Report on Nuclear Power Plant License Renewal, unpublished NUMARC Series Reports, Report No.: 90-1 to 90-10, April 1990, Washington, DC, available at the Nuclear Regulatory Commissions's Public Document Room.

condensate polishing systems. It should be noted that no distinction is made here between PWR and BWR waste streams. It is assumed that BWR and PWR generate the same spectrum of Class A waste, except in varying volumes. However, this is not necessarily the case for the presence of some radionuclides, basis for scaling factors, and concentration distributions (ROB91). Also, there are some differences among waste streams (e.g., filter cartridges and resin beds).

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

7.2.1 Waste Streams and Forms

Dry Waste

A wide variety of materials become contaminated during plant operation and maintenance, including paper, cloth, wrappings, glass, plastics, wood, insulation, scrap metals, and other miscellaneous disposable items. Protective clothing items are also generated, including gloves, coveralls, shoe and head covers, and respirator cartridges. Occasionally, other items are also disposed of as waste, including small metal parts, minor components, hardware, instrumentation, spent HEPA and charcoal filters, etc. Much of this waste is compressible and some of it is also combustible. Current practices involve segregating compressible from non-compressible waste streams. Utilities routinely compact dry active waste.

Dry Solids and Equipment

Dry solids typically include bulkier or voluminous waste. Much of this waste is not compressible, nor can it be incinerated. Such waste includes contaminated tools, valves, piping, pumps, motors, filters, instrumentation, structural steel, spent-fuel racks, wood, concrete, and soils. Dry solid waste is typically disposed of intact, cut-up or disassembled and decontaminated to reduce bulk volumes, or immobilized, e.g., in concrete.

Wet Waste

Radioactivity removed by plant purification systems is collected in filters and ion-exchange resins. Spent filters and resins are periodically replaced and processed prior to disposal. Processing generates wet residues, concentrates, and sludge which are solidified and placed in approved waste shipping and disposal containers (e.g., high integrity containers and liners). Sludge and concentrates typically contain spent resins and resin fines, filter cakes, dissolved and suspended solids, metal oxides, oils, chelated agents, sulfates, salts, etc. Spent resins may contain 45 to 55 percent water by weight, even after dewatering.

Concentrated liquids are characterized by suspended solids, e.g., 11 percent for PWR boric acid waste, 25 percent for BWR sodium sulfate waste, and up to 25 percent for laboratory and laundry liquid waste. Spent filter cartridges are usually placed in high integrity containers or solidified prior to being shipped for disposal.

Liquid Waste

Nuclear power plants produce relatively large quantities of liquid wastes. However, contaminated liquids are not shipped for disposal, but are processed via filtration, ion-exchange, or evaporation. The resulting waste residues are collected and processed for disposal. The treated water is re-used or released in accordance with plant radiological effluent technical specifications or radiological effluent controls contained in the offsite calculation manual. Such activities are monitored to ensure compliance with applicable regulations (10 CFR 20, Appendix I to 10 CFR 50, and Generic Letter 89-01, NRC89) established by the NRC and state-imposed National Pollution Discharge Elimination System (NPDES) permits.

Gaseous Effluent Treatment Systems Waste

Plant effluent treatment systems routinely discharge gaseous waste to the atmosphere. These effluents are passed through HEPA and activated charcoal filtration systems before being released into the environment. Periodically, such filters are removed and replaced with new ones. The resulting waste includes spent-filter media, including roughing and HEPA filters and charcoal beds. Roughing and HEPA filters are usually compacted to reduce the final disposal volume, while spent charcoal is disposed of in its bulk form.

Unusual Waste

Nuclear power plants also produce unusual waste streams during major repair activities. Such activities, for example, include the replacement of PWR steam generators or BWR recirculation pipes, generator or condenser tubes repairs, and chemical decontamination. Major repair work also results in the generation of additional dry active, solid, mixed, and wet waste, which are processed or handled as discussed above.

Other waste streams consist of irradiated components, e.g., control rods, fuel channels, in-core instrumentation and detectors, shim rods, core internals, and flux wires. At times, some of these waste materials had to be disposed of as Class B or C waste because of elevated radionuclide concentrations.

7.2.2 Radionuclides and Volumes of Waste Shipped for Disposal

When compared to industrial waste generators, nuclear power plants tend to generate relatively fewer long-lived nuclides. Table 7-2 lists radionuclides that capture over 99 percent of the total activity shipped as Class A waste. Of the 19 nuclides listed, seven are characterized by half-lives of less than 100 days and four have half-lives between 100 days and one year. Eight have half-lives greater than one year and, of these, only C-14 and Ni-63 have a half-life greater than 100 years.

As with other waste generators, utilities occasionally use radioactive materials obtained from outside sources, e.g., radiochemical laboratories and sealed source manufacturers. Such radioactive materials are primarily used for laboratory applications, non-destructive testing, and radiation equipment calibration. However, the amounts of radioactivity used in such applications are small as compared to that generated in waste associated with plant operations.

Table 7-3 presents the total activity and volume of waste shipped for disposal by nuclear utilities from 1986 to 1990. The data include brokered and unbrokered shipments for Class A, B, and C waste. The total utility waste volumes have been declining, while maintaining about the same share of the total waste volumes generated by all sectors. In the aggregate, power plants are generating just over half of the volume and about 80 percent of the activity of the nation's waste, 52 to 57 percent (EGG89, EGG90, MIM91). The highest activity levels were shipped in 1989. From 1986 to 1990, power plants generated 73 to 85 percent of the total low-level waste activity produced nationally by all waste generators.

Table 7-4 presents the volumes and activities of waste shipped by Compact and State. At the regional level, waste activity shipped for disposal ranges from 21 to 746,500 Ci. Six regions shipped nearly 97 percent of the total waste activity. These regions, in decreasing order, include the Northeast, Central Midwest, Midwest, Southeast, Appalachian Compacts, and the State of New York. The balance of the Compacts and States typically generate individually less than one percent each.

Table 7-4 also presents the volumes of waste shipped for disposal. Five regions account for nearly 77 percent of the total waste volume generated nationally. In decreasing order, these regions are the Southeast, Central Midwest, Appalachian, Northeast, and the Midwest. All other regions or States generate lower amounts, typically less than seven percent each.

Table 7-2 Major Waste Radionuclides Reported by Utility Nuclear Power Plants[a]

	≤100 Days	≤1 Year	≥1 Year	≥100 Years
	Cr-51	Mn-54	H-3	C-14
	Co-58	Zn-65	Cs-137	Ni-63
	Fe-59	Ag-110m	Fe-55	
	Zr-95	Ce-144	Co-60	
	Nb-95		Ru-106	
	Ru-103		Cs-134	
	Sb-124			
n=	7	4	6	2
%=	36.8	21.1	31.6	10.5

(a) See text for details.

Table 7-3 Yearly Waste Volumes and Activity Levels Generated by Utility Nuclear Power Plants[a]

Year	Volume (m^3)	Volume (%)	Activity (Ci)	Activity (%)
1986	2.93E+4	57.3	1.70E+5	73.4
1987	2.80E+4	53.6	2.19E+5	85.5
1988	2.29E+4	56.8	2.13E+5	82.2
1989	2.39E+4	52.0	7.25E+5	83.7
1990	1.82E+4	56.2	4.33E+5	79.2
Total	1.22E+5	55.0	1.61E+6	79.[illegible]

(a) Data extracted from NUREG-1418 (NRC90), MIMS on-line service, and DOE/EG&G MIMS (EGG90). Waste volume and activity percentages are based on totals generated by all sectors for each year. 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 7-4 Utility Waste Volume and Activity by Compact Regions and States - Aggregate Practices from 1986 to 1990[a]

	Volume		Activity	
Compact/State	Vol. (m^3)	Percent	Act. (Ci)	Percent
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. No waste were disposed of by Puerto Rico, Rhode Island, New Hampshire, and District of Columbia for 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.

7.2.3 Volume Allocation

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (Public Law 99-240) authorizes each site to limit the amounts of waste it receives for disposal. The Act establishes annual and seven-year ceilings for each of the three disposal sites. The Act also assigns "regular" and "unusual" waste volume allocations for individual nuclear power plants. The Act assigns waste volume limits for two time periods, January 1, 1986 to December 31, 1989, and January 1, 1990 to December 31, 1992. Volume allocations not used in the first period may be carried forward into the second. Waste volume allocations may also be transferred between plants. By 1989, nuclear power plants shipped over 104,000 m^3 of waste for disposal (DOE90b). This volume represents 56 percent of the total allocation over the period of 1986 to 1989. Five utilities have used 20 percent of the unusual waste volume allocation, i.e., 4,600 m^3 (DOE90b). The fact that only 56 percent of the 1986-1989 volume allocation has been used implies that utilities have been scrutinizing waste generation practices and implementing waste minimization and volume reduction measures. Some waste are also treated by processors (such as SEG, Quadrex, etc.) for further volume reduction. Table 7-5 presents annual average waste generation rates for plants that are in the allocation program. The volumes reflect routine operations only. Waste generated during unusual decontamination or refurbishment activities are accounted for under a separate allocation system.

A review of Table 7-5 indicates that plants with BWRs generate about twice as much waste as those with PWRs. On average, PWR plants generate nearly 10,000 ft^3/yr (283 m^3/yr), while BWR plants produce about 20,000 ft^3 (566 m^3) per year. These estimates are not presented on a per unit basis due to the use of shared facilities at multiple unit sites. In addition, several plant sites include new units that have come into commercial operation during the four-year allocation period. Accordingly, waste generation rates for newer plants may not b comparable to that of older reactors. This is the case for Comanche Peak Unit 1, Limerick Unit 2, and Seabrook, all with less than one year of operation.

Unusual volume allocations are not included in Table 7-5 since it is assumed that they may not necessarily reflect routine waste generation practices during normal operations. Such waste would include equipment or hardware resulting from repairs or modifications (backfit rule) and waste from spent-fuel pool re-racking (NRC83c, NRC86c, EPR88, EPR89a). Table 7-6 presents selected data characterizing unusual waste and associated volumes. As can be seen, waste volumes vary significantly from 46.0 to 75,000 ft^3 (1.3 to 2,124m^3, respectively).

Table 7-5 Average Annual Utility Waste Generation Rate Estimates Per Site[a]

Plant	Plants No.	Type	Vol. (ft^3) Disposed	Vol. Alloc. Used (%)	Time (yr)	Average gen. rate (ft^3/yr)
Arkansas	2	PWR	39,430	47	4	9,900
Beaver Valley	2	PWR	23,681	44	4	5,900
Big Rock Pt	1	BWR	8,650	9	4	2,200
Braidwood	2	PWR	6,314	36	1	6,300
Browns Ferry	3	BWR	145,097	44	4	36,300
Brunswick	2	BWR	112,087	51	4	28,000
Byron	2	PWR	39,960	71	4	10,000
Callaway	1	PWR	22,477	54	4	5,600
Calvert Cliffs	2	PWR	26,280	31	4	6,600
Catawba	2	PWR	33,271	44	4	8,300
Clinton	1	BWR	26,884	77	2	6,700
Comanche Peak	1	PWR	(b)	0	<1	---
Cook	2	PWR	57,391	44	4	14,300
Cooper	1	BWR	49,932	53	4	12,500
Crystal River	1	PWR	38,623	78	4	9,700
Davis Besse	1	PWR	18,207	44	4	4,500
Diablo Canyon	2	PWR	23,127	31	4	5,800
Dresden	2	BWR	214,598	72	4	53,600
Duane Arnold	1	BWR	37,495	40	4	9,400
Farley	2	PWR	62,074	63	4	15,500
Fermi	1	BWR	34,534	45	2	17,200
Fitzpatrick	1	BWR	57,734	62	4	14,400
Fort Calhoun	1	PWR	16,838	40	4	4,200
Ginna	1	PWR	25,021	60	4	6,300
Grand Gulf	1	BWR	58,541	53	4	14,600
Haddam Neck	1	PWR	35,715	85	4	8,900
Shearon Harris	1	PWR	13,265	62	2	6,600
Hatch	2	BWR	141,555	64	4	35,400
Hope Creek	1	BWR	27,063	51	3	9,000
Indian Point 2	1	PWR	46,915	56	4	11,700
Indian Point 3	1	PWR	11,665	28	4	2,900
LaSalle	2	BWR	90,639	48	4	22,700
Limerick[b]	2	BWR	72,675	98	3	24,200
Maine Yankee	1	PWR	21,796	52	4	5,400
McGuire	2	PWR	83,773	85	4	21,000
Millstone	3	2PWR/1BWR	98,899	60	4	25,000
Monticello	1	BWR	33,202	35	4	8,300
Nine Mile Pt	2	BWR	84,134	68	4	21,000
North Anna	2	PWR	61,259	62	4	15,300
Oconee	3	PWR	98,552	67	4	24,600
Oyster Creek	1	BWR	53,492	69	4	13,400
Palisades	1	PWR	29,278	70	4	7,300

Table 7-5 Average Annual Utility Waste Generation Rate Estimates[(a)], Cont'd

Plant	Plants No.	Plants Type	Vol. (ft^3) Disposed	Vol. Alloc. Used (%)	Time (yr)	Average gen. rate (ft^3/yr)
Palo Verde	3	PWR	79,527	81	3	26,500
Peach Bottom	2	BWR	168,358	80	4	42,100
Perry	1	BWR	37,483	84	2	18,700
Pilgrim	1	BWR	55,602	59	4	13,900
Point Beach	2	PWR	18,370	22	4	4,600
Prairie Island	2	PWR	15,948	19	4	4,000
Quad Cities	2	BWR	111,774	60	4	27,900
River Bend	1	BWR	57,297	84	4	14,300
Robinson	1	PWR	25,918	60	4	6,500
San Onofre	3	PWR	53,480	43	4	13,400
Seabrook	1	PWR	(b)	0	<1	---
Sequoyah	2	PWR	67,268	68	4	16,800
South Texas	1	PWR	1,985	33	1	2,000
St. Lucie	2	PWR	56,155	57	4	14,000
Summer	1	PWR	28,027	57	4	7,000
Surry	2	PWR	70,580	72	4	17,600
Susquehanna	2	BWR	126,206	67	4	31,600
TMI-1	1	PWR	95,062	56	4	23,800
Trojan	1	PWR	34,812	71	4	8,700
Turkey Point	2	PWR	38,549	39	4	9,600
VT-Yankee	1	BWR	26,371	28	4	6,600
Votgle	2	PWR	4,878	25	2	2,400
Waterford	1	PWR	32,068	86	4	8,000
WNP-2	1	BWR	54,921	50	4	13,700
Wolf Creek	1	PWR	20,401	59	4	5,100
Yankee Rowe	1	PWR	25,700	61	4	6,400
Zion	2	PWR	46,923	56	4	11,700

Overall Estimates[(c)]	PWR	BWR
Range:	2,000 - 26,500	2,200 - 53,600
Arithmetic mean:	9,800	20,500
Geometric mean:	8,200	16,800

(a) Based on the DOE's 1989 Report to Congress (DOE90b).
(b) Designates plants with <1 year of operation, for which waste generation rates are not comparable to older plants.
(c) Years of plant operations are approximated based on NRC91. No corrections were made for the number of reactor units per site. Millstone was excluded in estimating overall averages as data include both PWR/BWR waste volumes. 1 m^3 = 35.3 ft^3.

Table 7-6 Examples of Unusual Utility Waste Streams and Volumes[a]

Waste Stream	Waste Volumes (ft^3) Maximum	Minimum	Actual or Average
Recirculation pipes			
Decon volume:	29,700	(b)	(b)
Disposal volume:	(b)	(b)	5,470
	(b)	(b)	6,000
Sent-Fuel Rack			
Before Decon:	(b)	(b)	6,800
Disposal volume:	11,970	1,750	6,300
Decon volume:	27,120	7,000	16,373
Steam generators:	75,000	5,000	(b)
Condenser tubes:	50,000	19,000	27,500
Feedwater heaters:	4,500	2,620	3,600
Thermal shield removal:	(b)	(b)	20,000
Contaminated cooling fan coils:	(b)	(b)	4,600
Refueling machine mast replacement:	(b)	(b)	1,200
Asbestos:	4,400	3,800	4,100
Dirt/Sand:	44,400	1,800	15,550
Torus sandblasting:	16,400	14,100	15,250
Contaminated filter cake:	(b)	(b)	6,600
Chemical decon solidified volume:	700	46	173
Decon of low pressure turbine disk blades Disposal volume:	(b)	(b)	2,304

(a) Extracted from EPRI 1988 Radwaste Workshop Proceedings (EPR89a), EPRI Radwaste Generation Survey (EPR88), and Decontamination Waste Management (EPR85). To convert waste volume to cubic meters, multiply cubic feet by 0.0283.

(b) Data not provided or cannot be derived from the given information.

7.2.4 Other Studies and Evaluations

Waste generation practices for nuclear power plants have been the object of scrutiny because there is a concern that disposal sites might reach their annual volume allocation ceilings. Power plants typically generate about half of the nation's total waste volume. Recently, this concern has been alleviated since the waste volume disposed by the end of 1989 is only 56 percent of total regular reactor allocation (DOE90b). Waste generation rates have been evaluated by the NRC in support of the development of 10 CFR 61 - Licensing Requirements for Land Disposal of Radioactive Waste (NRC81a, NRC82, NRC86a). Similarly, the Electric Power Research Institute (EPRI) has initiated two relevant studies, among others, addressing the characterization of power plant low-level waste (EPR84, EPR88, EPR89b).

The results of an Electric Power Research Industry survey are summarized in Table 7-7. The tabulation presents estimates of the aggregate generation rate for 56 PWR and 27 BWR units based on waste generation and disposal practices for 1985 and 1986. Ranges characterize variations associated with plants located at fresh or salt water sites, plants with and without evaporators, and plants equipped with filter/demineralizer vs deep-bed condensate polishing systems.

As noted earlier, BWRs generate about twice as much waste as PWRs, with the range for each type of plant being narrower than that shown in Table 7-5. In general, PWR plants located at salt water sites tend to produce nearly 20 percent more waste than those using fresh water for cooling. Salt water plants generate more dry waste (59 percent), but less wet waste (44 percent). PWRs without evaporators also generate slightly greater waste volumes, about eight percent more overall. By waste streams, such plants produce 48 percent more dry waste and 44 percent less wet waste. For PWRs, dry active waste makes up from 56 to 82 percent of the total volume, depending upon plant features.

Wet waste is processed prior to disposal by solidification and dewatering, which tend to increase the total waste. Volume increase factors generally range from 1.9 to 2.7 for solidified waste. The volume increase of dewatered bead resin and powdered resin sludge has been observed to vary from 1.1 to 1.26. In some cases, the use of a high integrity container tends to increase the volume even for dewatered waste. In other instances, the gain from dewatering is negated by the volume increase associated with solidification. EPRI attributes these effects to void spaces and the effects of different media and geometries of the containers (EPR88).

Table 7-7 Typical Plant Waste Generation Rate Summary[a]

Waste Forms	PWR Average	PWR Range	BWR Average	BWR Range
	Generation Rates - ft^3/unit-yr[b]			
Average Dry Waste				
Compacted:	4,300	3,550 - 5,350	7,850	6,350 - 8,600
Non-compacted:	2,100	1,300 - 2,950	4,900	2,850 - 7,300
Filters:	200	100 - 250	50	0 - 250
Subtotal:	6,600	4,950 - 8,500	12,800	9,300 - 15,300
Average Wet Waste				
Bead resins:	1,100	1,050 - 1,100	2,400	1,500 - 3,550
Powdered resin & sludge:	400	50 - 600	4,350	2,050 - 6,000
Concentrates:	800	0 - 2,500	1,750	450 - 6,200
Oils:	300	150 - 350	1,100	850 - 1,200
Miscellaneous:	150	50 - 350	200	50 - 300
Subtotal:	2,750	1,900 - 3,900	9,750	7,350 - 13,000
Average Totals:	9,350	8,750 - 10,400	22,550	21,650 - 22,900

(a) Extracted from EPRI Radwaste Generation Survey: BWR, Vol. 1, Table 7-5; PWR, Vol. 2, Table 7-4 (EPR88).

(b) Based on waste shipped for disposal in 1985 and 1986 for 27 BWR and 56 PWR units. To convert waste volume to cubic meters, multiply cubic feet by 0.0283.

For BWRs, overall differences in waste volumes among plants located at fresh vs salt water sites and those equipped with evaporators or deep-bed condensate polishing system is not as large as that of PWRs, typically less than six percent. The more significant differences, however, are between dry and wet waste volumes, with the resulting differences nearly negating one another. For example, salt water plants generate about 25 percent more dry active waste and 28 percent less wet waste than fresh water plants. Plants with evaporators were observed to produce about 28 percent less dry waste but 30 percent more wet waste than plants without evaporators.

Finally, plants located at fresh water sites and equipped with deep-bed condensate polishing systems tend to generate about 32 percent less dry waste, but 45 percent more wet waste. For BWRs, dry waste volumes also vary from about 42 to 68 percent of the total generated. Wet waste streams reflect volume increase factors ranging from two to three for solidified waste and about 1.2 for dewatered resins and powdered resin sludge.

7.3 Detailed Characterization of Waste Properties

The characterization of utility waste is based on information obtained from the National Low-Level Waste Management Program database, known as "MIMS" (EGG90). This information was also supplemented by data obtained by direct access to the MIMS on-line service. Waste data were made available in electronic files for all three disposal sites, namely Barnwell, SC, Beatty, NV, and Richland, WA (MUN90, MUN91). The electronic files contain data at the shipment level for five years, from 1986 to 1990. However, data at the container level are available only for Beatty and Richland from 1988 to 1990. In both cases, the 1990 data reflect information posted by the end of November 1990.

A description of the program, discussion on data manipulation and selection, and validation process are provided in Section 2.0 and Appendix B. Appendix A presents copies of the shipping manifests.

7.3.1 Waste Characterization - Container Level

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

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

Table 7-3 reveals that the total volume and activity inventory of the shipments, both brokered and unbrokered and Classes A, B and C, generated in 1989 was 2.39E+4 cubic meters and 7.25E+5 Curies, respectively. Accordingly, this search represents about 17 percent of the volume and 0.8 percent of the waste shipped by all nuclear utilities. The reason that the percentage of the activity captured in the sort is much smaller than the percentage of the volume is that most of the activity is contained in Class B and C waste, which typically comprises less than 5 percent of the volume. For the same reason, the average gross radionuclide concentration in the sort is about 1.36 Ci/m^3, while the average gross radionuclide concentration in all nuclear power plant Class A waste is about 30 Ci/m^3.

Table 2-2 (Section 2.0) reveals that the total volume and activity inventory of brokered and unbrokered Class A waste shipped for disposal in 1989 was 2.27E+4 cubic meters and 2.31E+4 Ci, respectively. Accordingly, Class A waste represents about 95 percent of the volume of waste, but only about 3 percent of the activity. This sort captured about 18 percent of the 1989 volume of Class A waste and 24 percent of the activity and may be considered representative of the container level activity shipped for disposal by nuclear power plants.

It should be noted that the activity reported for some radionuclides is believed to be in fact overestimated (ROB91, ROL92). This is usually the case for C-14, Tc-99 or I-129 as the activity of these radionuclides is inferred by using scaling factors (ROB91). The scaling factor relates the presence of a radionuclide (that occurs at very low concentration or that is difficult to analyze) based on the presence of one that is easily detected (e.g., Co-60 or Cs-137). The presence of transuranics (e.g., Am-241) is also believed to be overestimated for the same reasons.

The presence of these radionuclides does not influence the classification status of the waste, but is important for the inventory of the disposal facility receiving the waste.

Exhibit 7-1 presents the concentration distributions of the principal radionuclides, and some of the less abundant but long-lived radionuclides captured by the sort. 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) Median	Average	1%ile	10%ile	90%ile	99%ile
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-[illegible]	4.7E-06	1.76E-05	4.7E-06	4.71E-06	4.71E-06	9.9E-05
	Total	4.52E+03						

* In activated metal, the limit is 35 Ci/m^3.
** In activated metal, the limit is 8.0 Ci/m^3.

Though the sort captured 85 radionuclides, these radionuclides constitute 4,524 of the 5,605 Curies (or about 81%) captured by the sort.

Appendix I presents all the non-brokered, Class A, container level data sorted by various waste streams. Each table in Appendix I presents the following information: waste class, waste stream or form and stabilization agent (if cited), number of shipping and container records captured by the sort, total waste volume and mass, and average waste stream density (inclusive of the overall container volume and weight of the waste and container).

Using the data obtained from Appendix I, Table 7-8 presents a comparison of selected radionuclide concentration distributions for specific waste streams. The results indicate that, for a given radionuclide, the resulting concentrations vary over several orders of magnitude depending on the waste. As may be expected, DAW, dry solids, and waste oil appear to have the lowest radionuclide concentrations, while evaporator bottoms, spent resins, and filter media are characterized by higher ones.

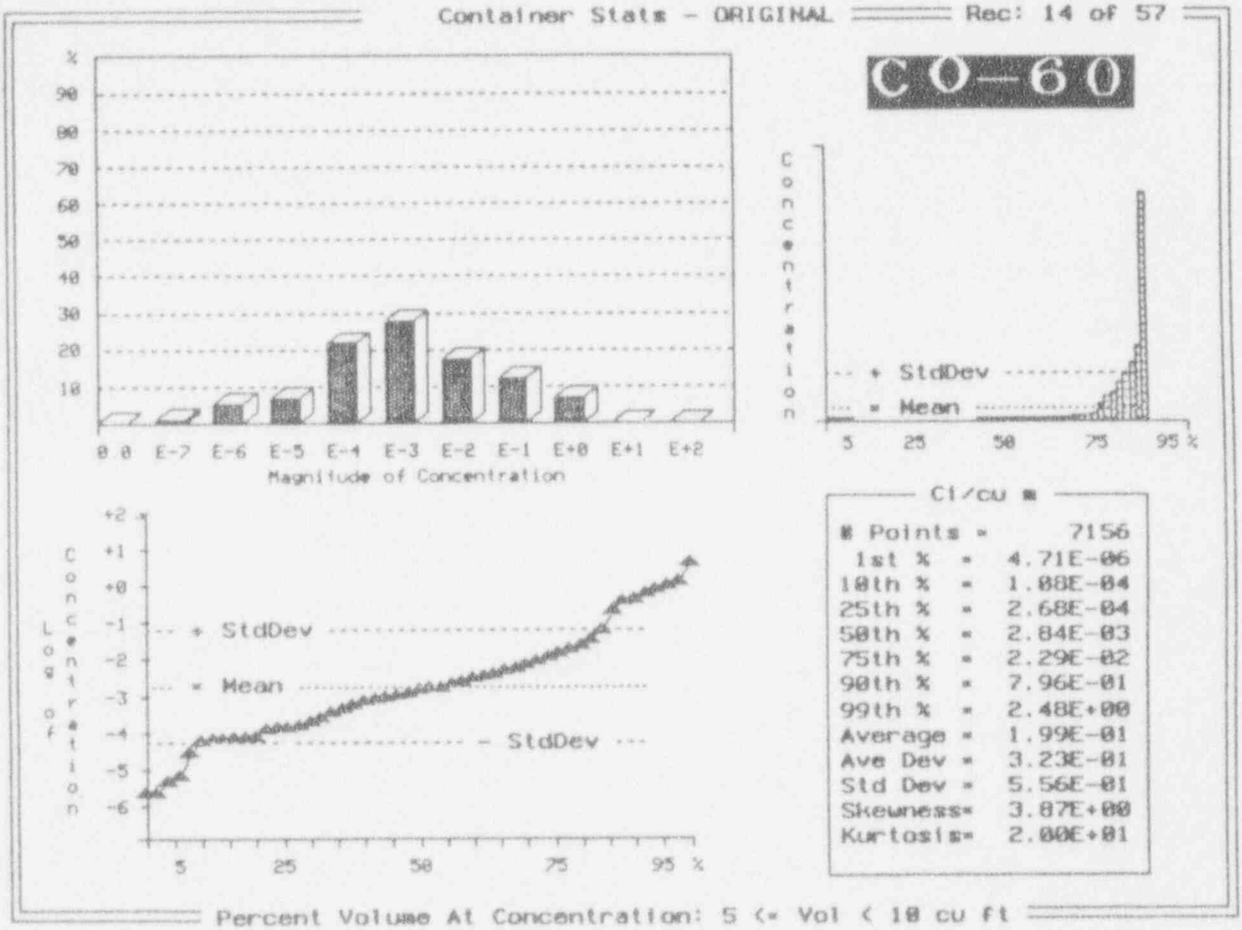
In all cases, the analyses are based only on 1989 information contained in the Beatty and Richland database. The analyses were performed using 1989 data since the database is complete for that year and because the waste volumes and levels of activity generated in 1989 were the highest over the past three years.

EXHIBIT 7-1

NUCLEAR POWER PLANT WASTE - CONTAINER LEVEL ANALYSIS

Number of shipping records captured:	437
Number of container records captured:	8,199
Number of isotope records captured:	101,538
Total activity of containers (Ci):	5.60E+03
Total volume of containers (m^3):	4.11E+03
Total weight of containers (kg):	3.81E+06
Total density (g/cm^3):	9.26E-01
Total concentration (Ci/m^3):	1.36E+00
Total concentration (pCi/g):	1.47E+06

Exhibit 7-1 (Continued)



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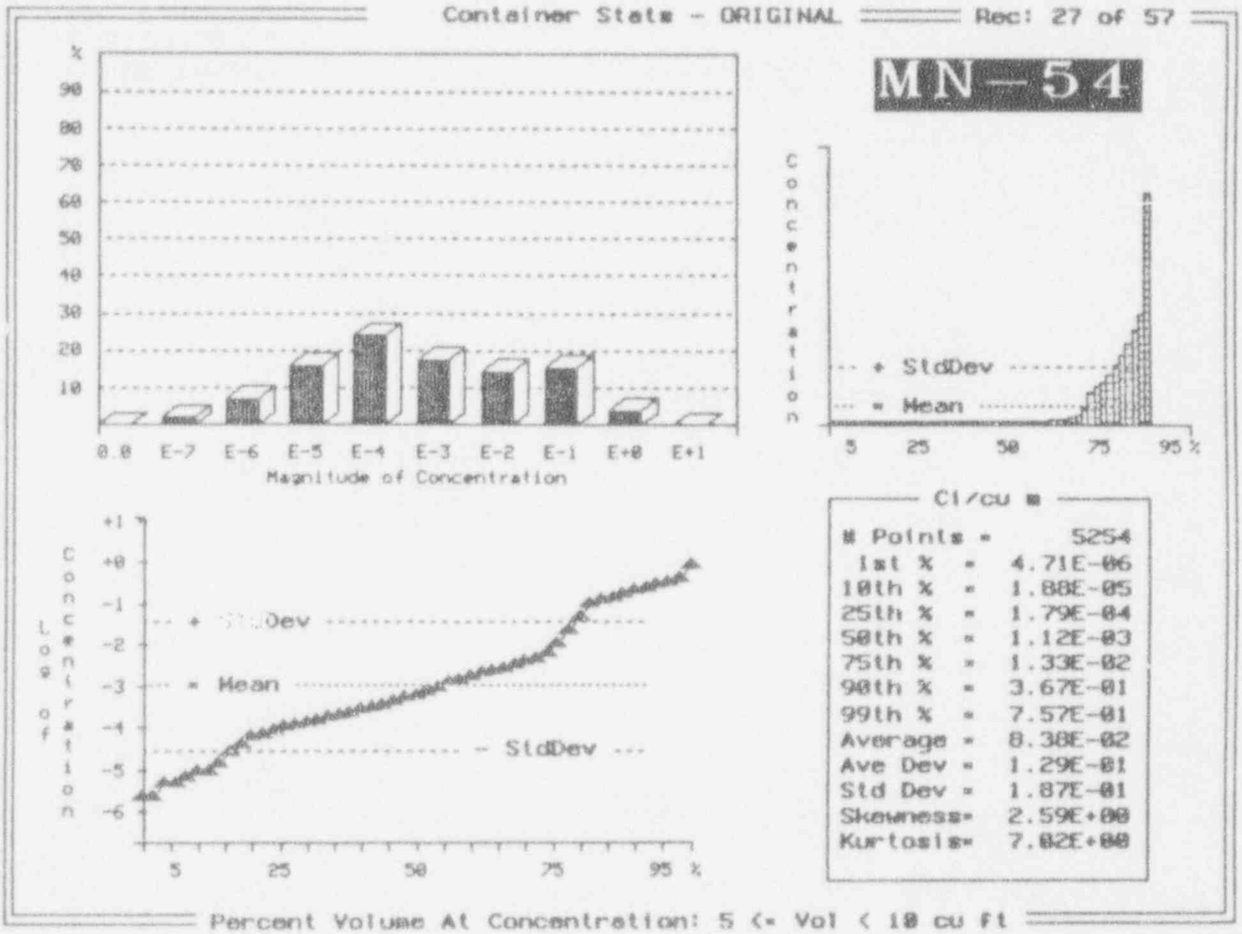

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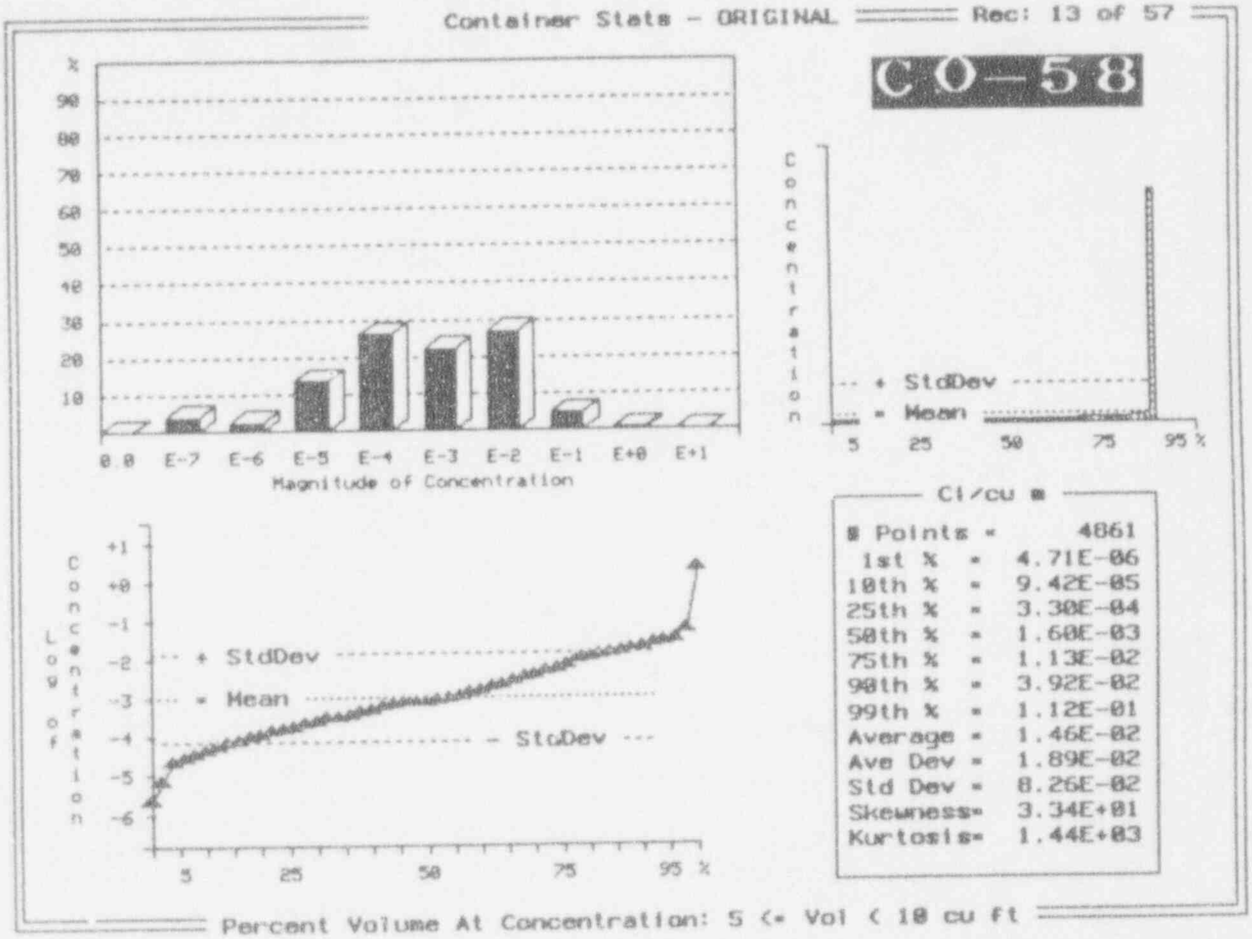

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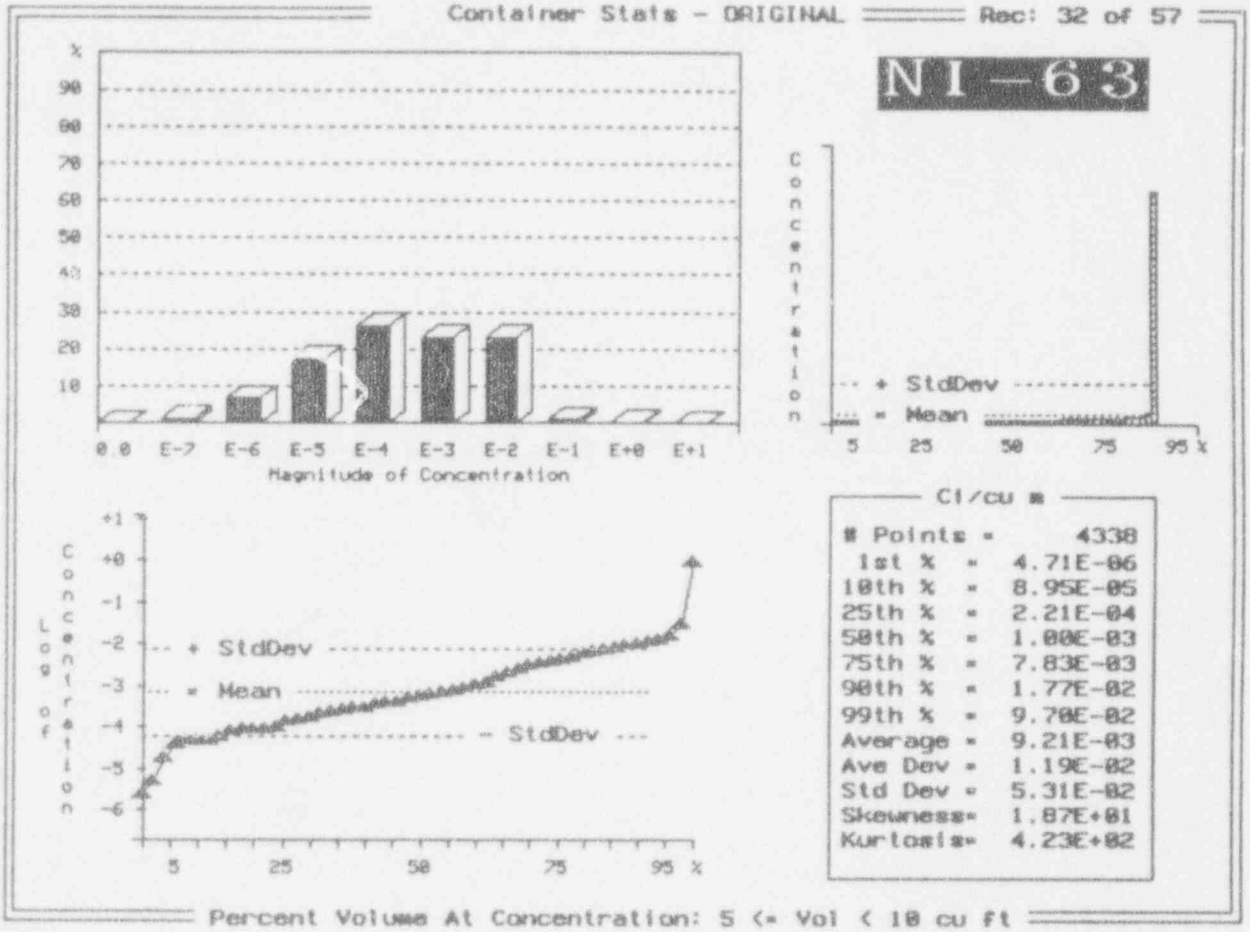

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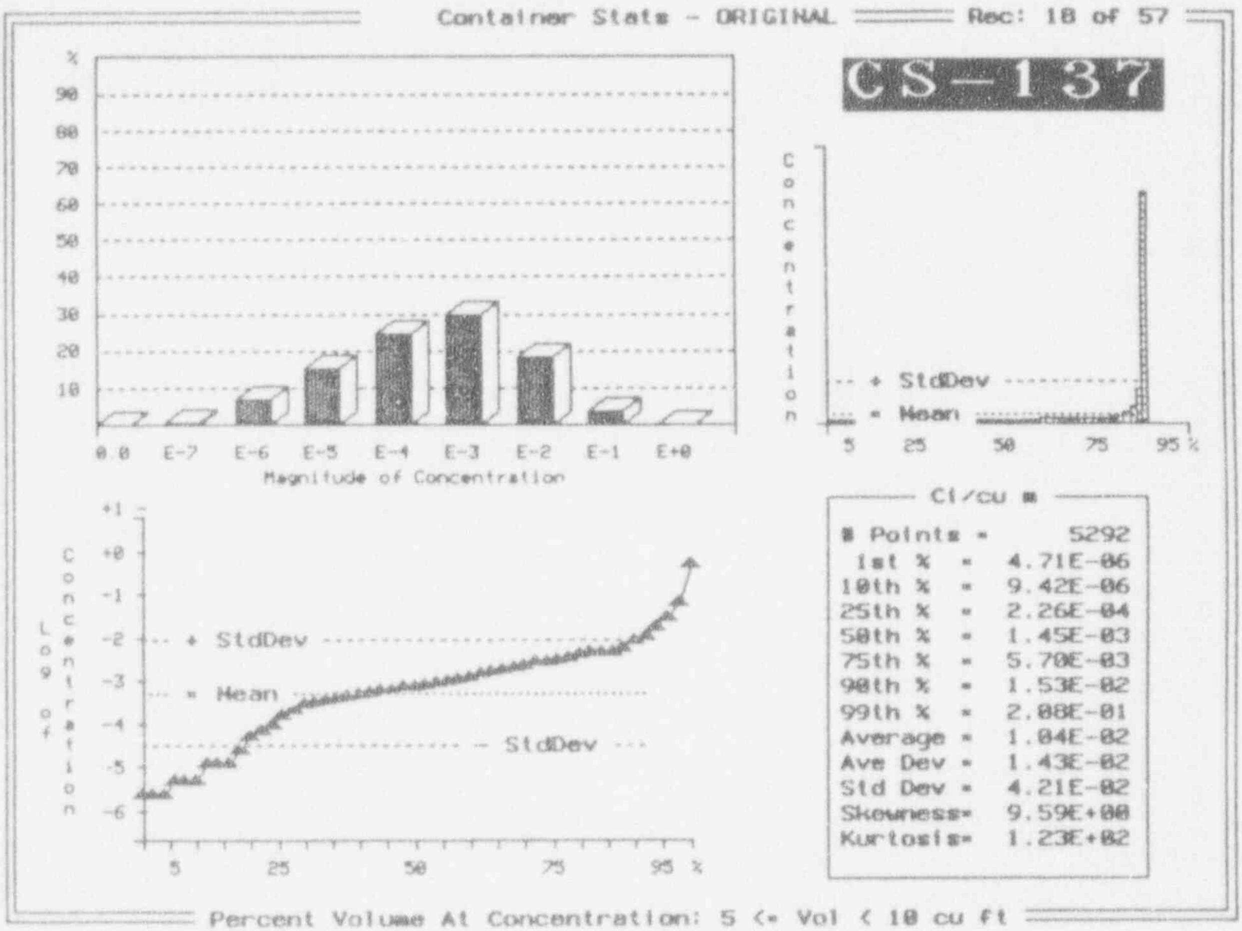

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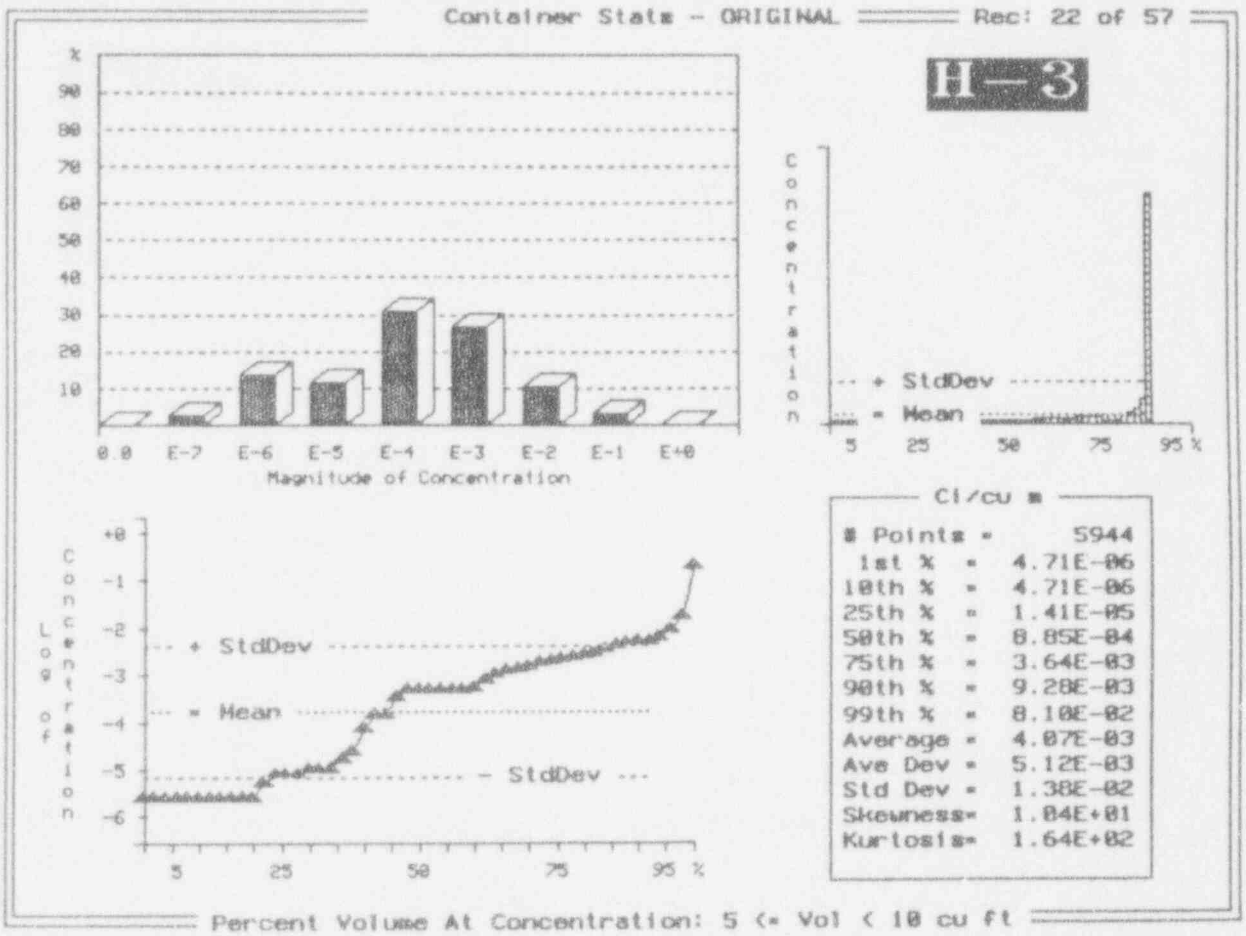

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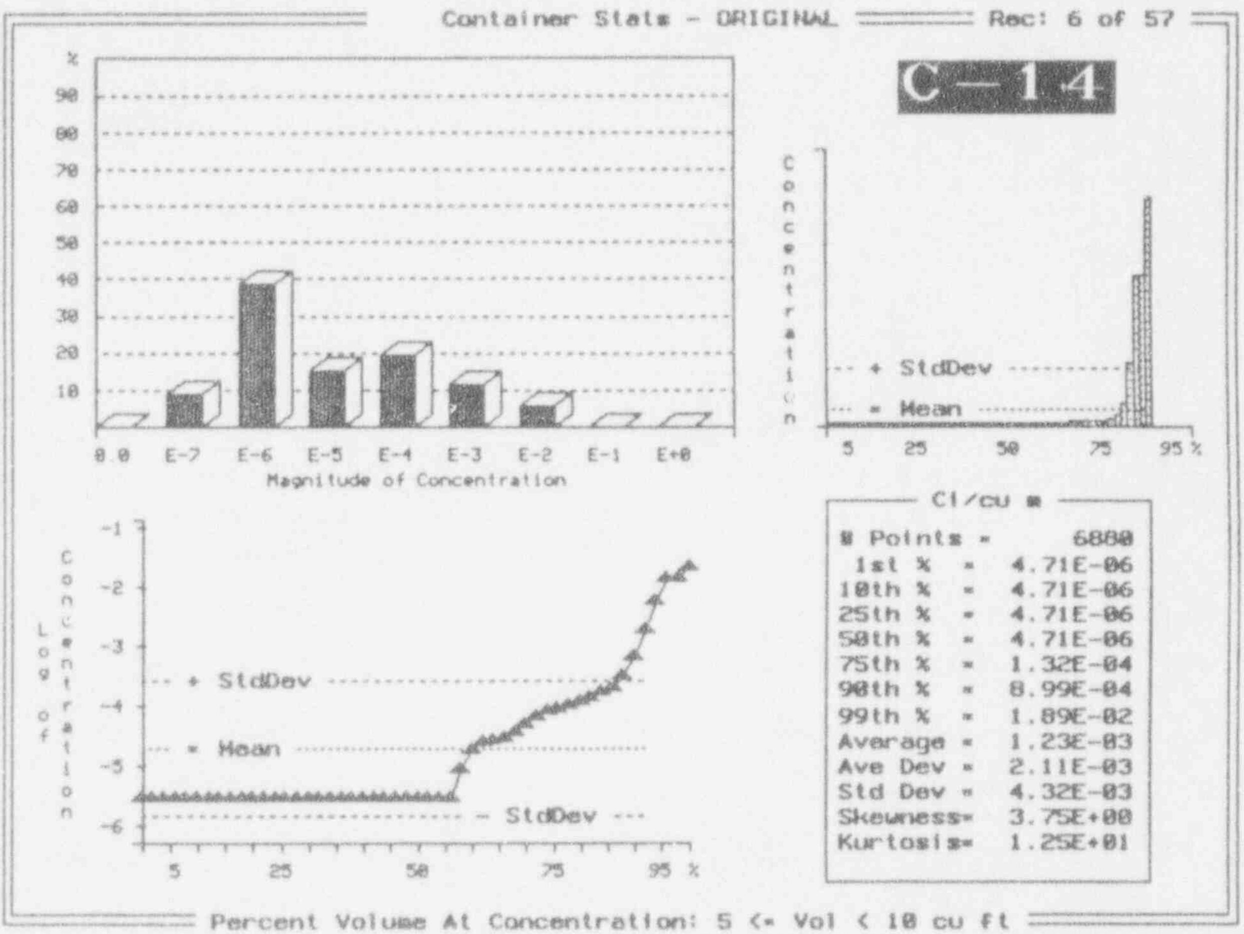

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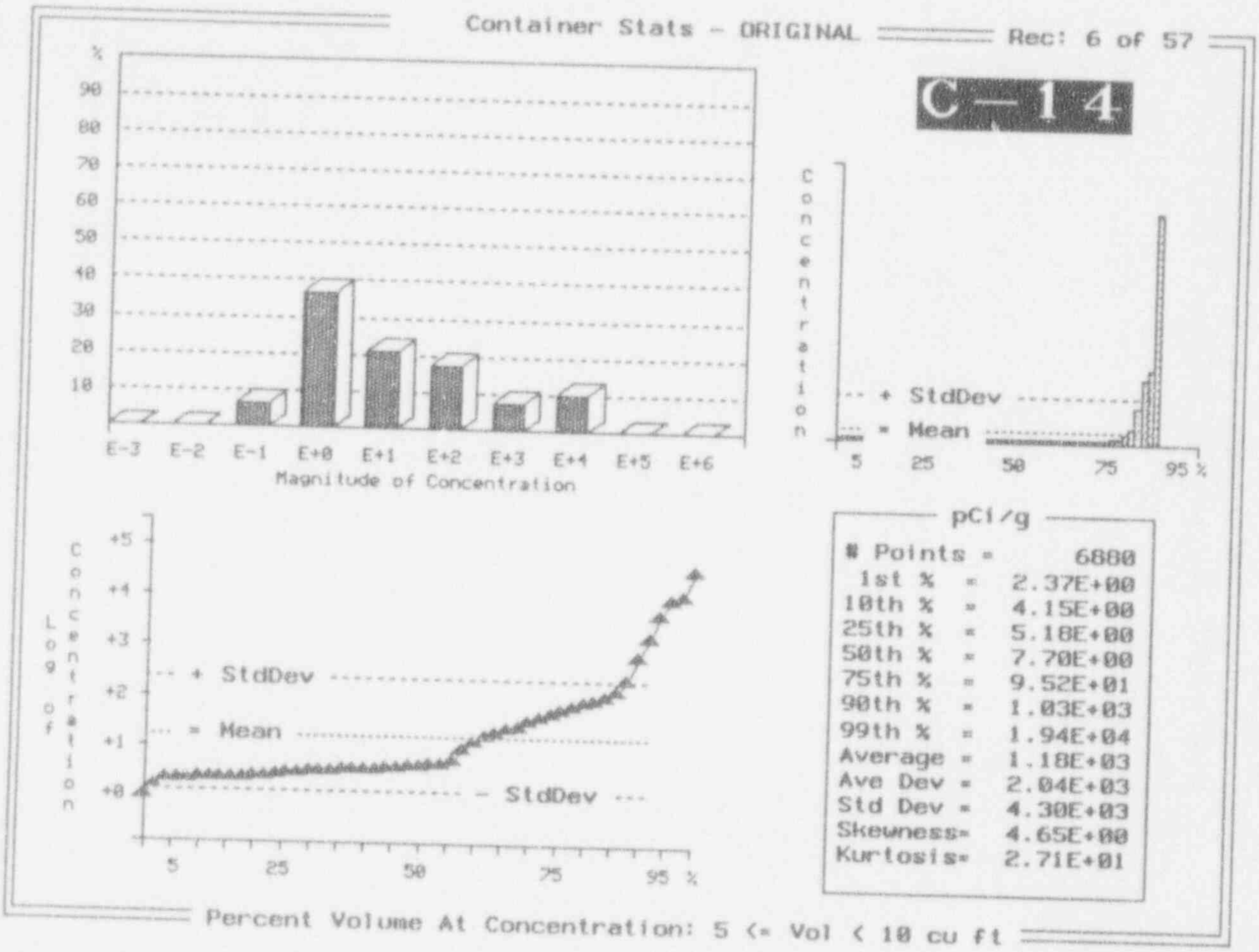

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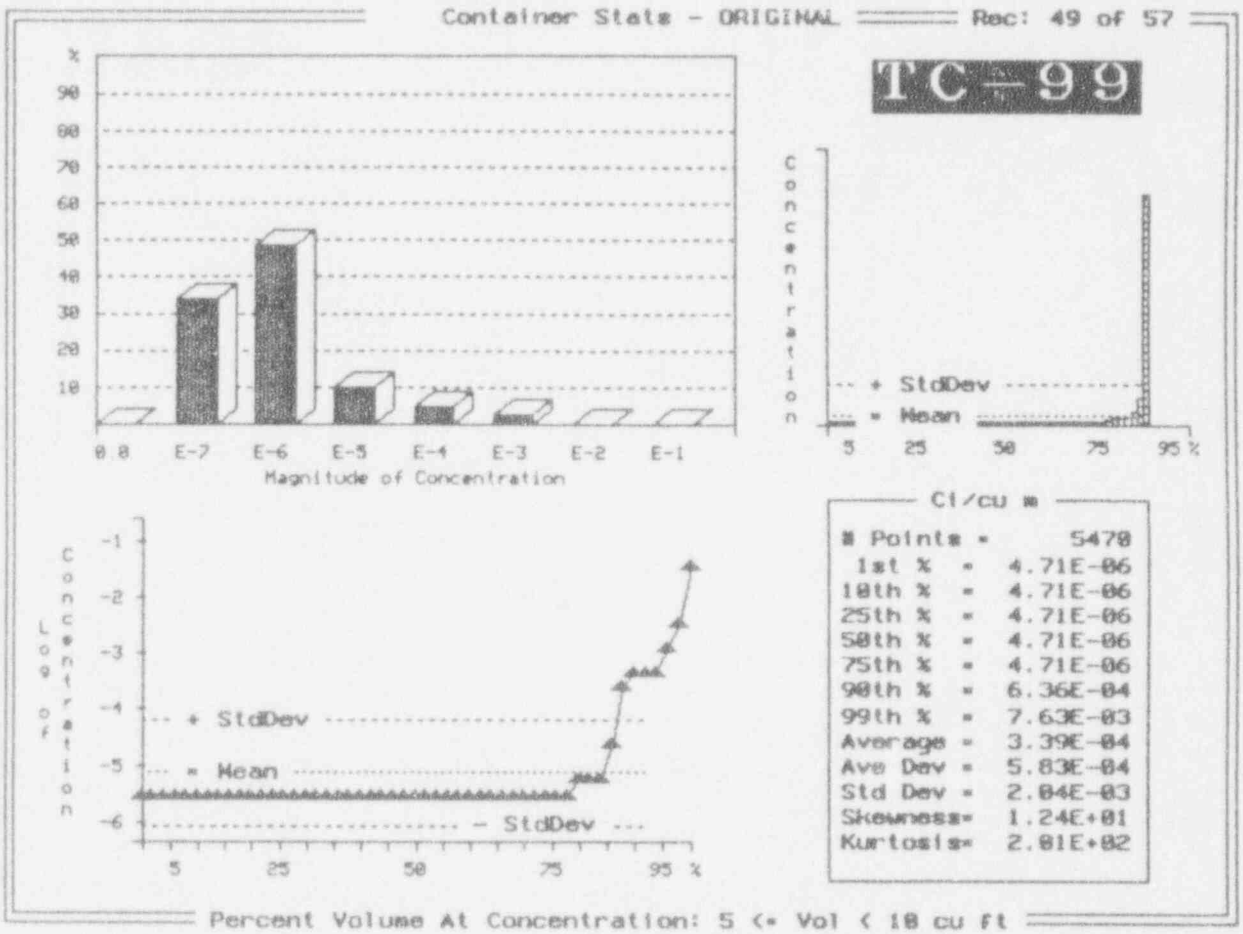


Table 7-8

Comparison of Selected Radionuclide Concentration Distributions in Container Level Nuclear Power Plant Waste

Radionuclide (Ci/m^3) - Percentile

	Co-60			Mn-54			Cs-137			H-3		
	1	50	99	1	50	99	1	50	99	1	50	99
Aggregate	4.7E-6	2.8E-3	2.5	4.7E-6	1.1E-3	7.6E-1	4.7E-6	1.5E-3	2.1E-1	4.7E-6	8.9E-4	8.1E-2
Dry Solid	4.7E-6	1.4E-3	2.7E-1	4.7E-6	4.2E-4	7.7E-2	4.7E-6	2.0E-4	2.3E-2	4.7E-6	5.2E-5	1.2E-2
Solidified Liquids	1.9E-3	2.3E-2	4.0E-1	4.5E-4	4.9E-3	4.0E-2	3.0E-3	1.1E-2	1.2E-1	2.0E-4	7.3E-4	3.9E-1
Dewatered Resin	2.1E-7	4.4E-2	7.1E+0	2.1E-7	6.2E-2	2.2E+0	2.1E-7	6.9E-3	2.5E-1	1.8E-7	4.3E-4	1.6E-1
Solidified Resin	7.0E-3	3.5E-2	3.4E-1	1.7E-3	8.0E-3	4.5E-1	1.3E-3	4.9E-3	1.4E-2	4.2E-4	2.0E-3	7.1E-3
Evaporator Bottoms	6.5E-3	1.2E+0	3.1E+0	9.3E-4	3.7E-1	1.0E+0	5.2E-4	1.2E-3	6.9E-2	2.5E-4	9.0E-4	1.1E-1
Compacted DAW	3.3E-5	2.2E-3	8.8E-2	3.3E-5	6.7E-4	9.3E-2	6.6E-5	4.1E-3	3.3E-1	4.7E-6	2.4E-3	2.0E-2
Non-Compacted DAW	4.1E-4	2.6E-3	4.8E-1	4.7E-6	6.0E-4	2.3E-1	1.3E-4	9.4E-4	5.7E-2	4.7E-6	1.5E-3	4.1E-2
Non-Cartridge Filter Media	2.0E-2	1.4E-1	7.4E-1	2.3E-2	1.8E-1	1.6E+0	2.0E-3	2.6E-2	5.8E-2	3.7E-4	5.2E-3	1.6E-1
Solidified Oils	4.7E-6	1.4E-4	3.5E-3				4.7E-6	9.4E-6	1.3E-3	4.7E-6	1.4E-5	1.7E-3

The analyses captured a varying number of shipping (12 to 125) and container (20 to 3,740) records depending on the waste stream. In decreasing volumes, these waste streams include:

- compacted dry active trash (26%),
- dewatered resins (18%),
- evaporator bottoms (16%),
- non-compacted dry active trash (15%),
- dry solids (12%),
- solidified oils (5%),
- non-cartridge filter media (4%),
- solidified resins (2%), and
- solidified liquids (2%).

The results indicate that stabilization and solidification agents are widely used. Such agents are used with dry solids, non-cartridge filter media, and both forms of dry-active waste, compacted and non-compacted waste. A wide spectrum of solidification agents are used in stabilized waste. The most common ones being cement, grout, butimen, and others with cementitious properties.

The results presented in Appendix I indicates that 19 radionuclides make up over 99 percent of the waste activity. These radionuclides include H-3, C-14, Cr-51, Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Zn-65, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Sb-124, Cs-134, Cs-137, and Ce-144. Other nuclides present at lower activity levels include Co-57, Sr-85, Sr-89, Sr-90, Tc-99, Sb-125, I-129, I-131, I-133, Ba-133, La-140, Ba-140, Pm-147, U-233, U-234, U-235, U-238, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Cm-242, Cm-244, etc.

The results reveal that radionuclide concentrations routinely vary over six orders of magnitude. Lower volume concentrations start at about 4.7E-06 Ci/m^3, while higher concentrations hover about 1.0E-01 Ci/m^3. Mass concentrations also vary from about 0.2 pCi/g to 1.0E+05 pCi/g, but most radionuclide concentrations fall within a narrower range, i.e., 10^1 to 10^4 pCi/g. Moreover, the results also indicate that, for a few radionuclides, the concentrations were higher still, up to 58 Ci/m^3 and 10^7 pCi/g. Radionuclides characterized by higher concentrations include H-3, Cr-51, Mn-54, Fe-55, Fe-59, Co-58, Ni-63, Co-60, Cs-134, and Cs-137.

Further examination of the data also reveals some noteworthy details. Certain radionuclide volume concentration values appear rather frequently, i.e., 4.71E-06 Ci/m^3, which is not always the case for mass concentration (pCi/g). The amount of activity reported in a 55-gallon drum is often cited as 1 uCi. Since a 55 gallon drum is 0.212 m^3, the resulting calculation yields a concentration of 4.71E-6 Ci/m^3. The reason for this artifact not occurring as frequently for mass concentrations is that there is much more variability in weights.

The often cited value of 1 uCi could also be interpreted as being an estimate of the lowest amount of activity in each drum. The activity is most likely lower than those observed here. However, it is not possible to confirm this with the database. In other instances, it is common for a few radionuclides to be characterized by identical concentrations. This is often the case for cesium, cobalt, curium, plutonium, and uranium.

Other limitations of the database are discussed in Section 2.2.

7.3.2 Radionuclide 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 from nuclear power plants shipped in 1989:

- 868 shipping manifests
- 8,125 cubic meters of waste
- 7.72E+06 kg of waste, 0.95 g/cm^3 average density
- 7,493 Ci of total activity, 0.92 Ci/m^3

Table 7-3 reveals that the total volume and activity inventory of the 1989 shipments, both brokered and unbrokered and Class A, B and C waste, was 2.39E+4 cubic meters and 7.25E+5 Curies, respectively. Accordingly, this search represents about 34 percent of the volume (the balance was shipped by brokers and a very small portion is Class B and C waste) and one percent of the activity of the waste shipped for disposal. In addition, the average gross radionuclide concentration in the sort is about 0.92 Ci/m^3, while the average gross radionuclide concentration in all government waste is about 30 Ci/m^3. The small percentage of activity captured relative to the total activity shipped is due to the fact that the sort does not include Class B and C waste, which contains the majority of the radioactivity.

Table 2-2 (Section 2.2) reveals that the total volume and activity of brokered and unbrokered Class A waste shipped in 1989 was 2.27E+4 cubic meters and 2.31E+4 Ci, respectively. Accordingly, Class A waste represents about 95 percent of the volume of waste but only about three percent of the activity. This sort, therefore, captured about 36 percent of the 1989 volume of Class A waste and 32 percent of the activity.

The overall container level radionuclide concentration results are fairly comparable to the shipment level result. Accordingly, the container level data appear to be representative of utility waste.

Exhibit 7-2 present the concentration distributions of the principal radionuclides contained in the shipments captured by the sort. The sorts are grouped into the following categories of shipment sizes:

- <10 cubic feet per shipment
- 10 to 50 cubic feet per shipment
- 50 to 100 cubic feet per shipment
- 100 to 500 cubic feet per shipment
- 500 to 1,000 cubic feet per shipment

In summary, the results of the search revealed the following concentration distributions for the principal radionuclides in 100 to 500 cubic foot shipment volume category. This category contains the majority of the waste by volume and activity:

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*	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	3.5**	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
	Total	5.76E+03						

* In activated metal, the limit is 8.0 Ci/m^3.
** In activated metal, the limit is 35 Ci/m^3.

Though the sort captured 86 radionuclides, the above radionuclides constitute 5,756 of the 7,493 Curies (or 77%) captured by the sort.

Appendix J supplements these results with radionuclide concentration histograms and curves sorted according to waste shipped by utilities to Barnwell and to Richland. Appendix J also includes the total number of shipping records (Barnwell and Richland) and containers (Richland only) captured in the analysis, and the total volumes and weights of the shipments.

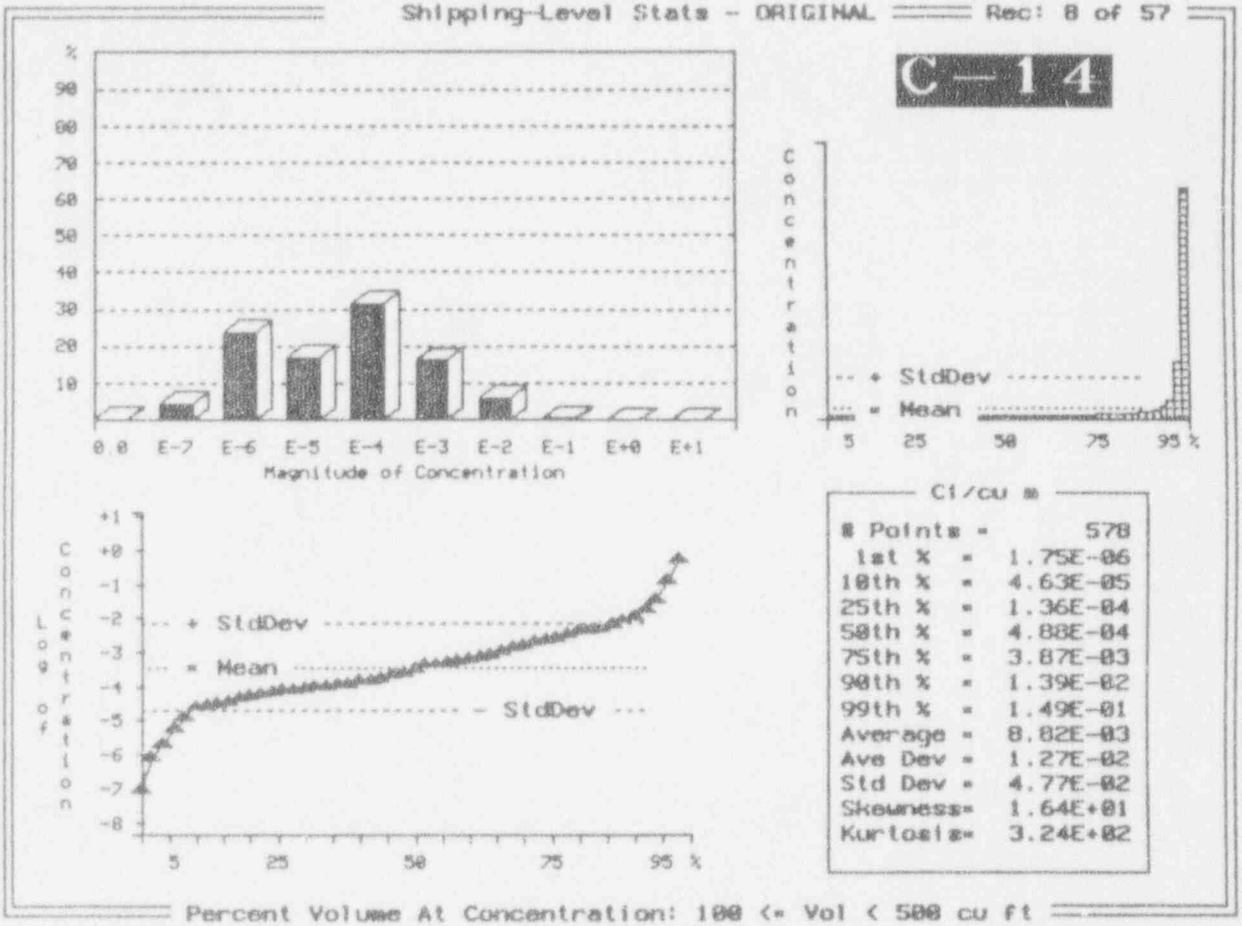
EXHIBIT 7-2

NUCLEAR POWER PLANT WASTE - SHIPMENT LEVEL ANALYSIS

Number of shipping records captured:	868
Number records with container data:	376*
Number of manifests captured:	0
Number of container records captured:	6,296
Number of isotope records captured:	11,615
Total activity of shipment (Ci):	7.49E+03
Total volume of shipments (m^3):	8.13E+03
Computed weight of shipments (kg):	7.72E+06
Total weight of containers (kg):	3.17E+06*
Nominal density (g/cm^3):	9.50E-01
Total density (g/cm^3):	9.41E-01*
Total concentration (Ci/m^3):	9.22E-01
Total concentration (pCi/g):	1.32E+06*

* For shipments with container data.

Exhibit 7-2 (Continued)



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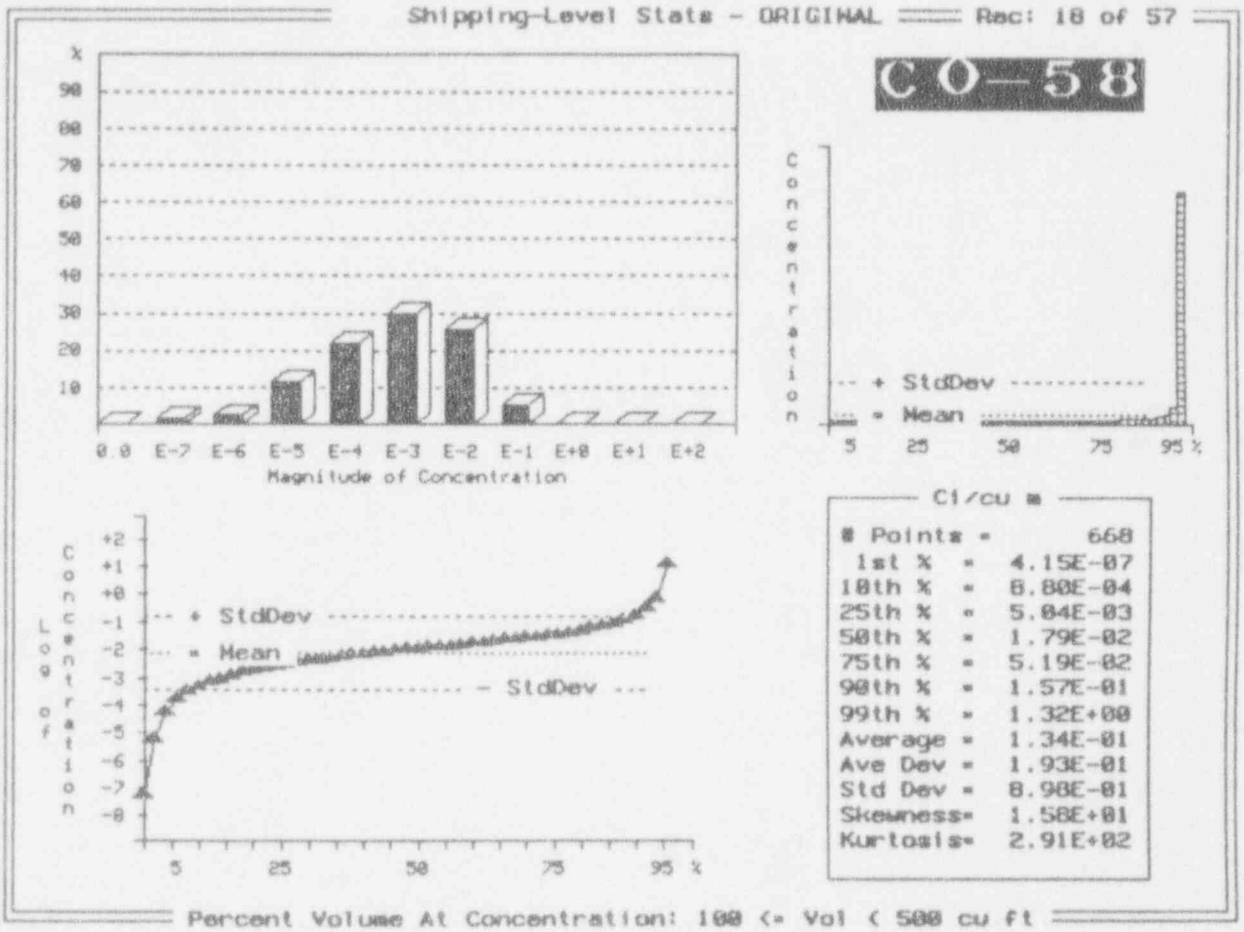

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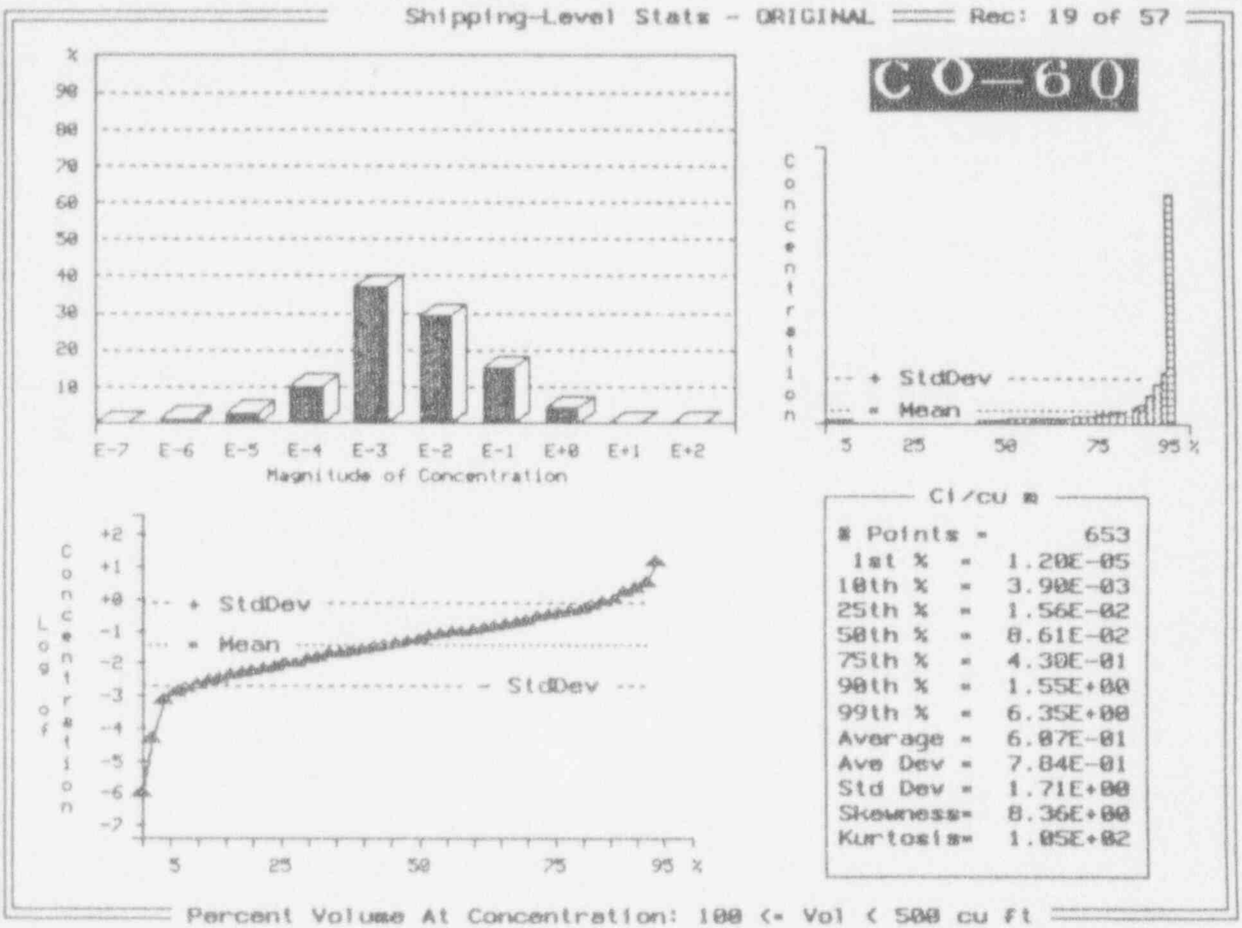

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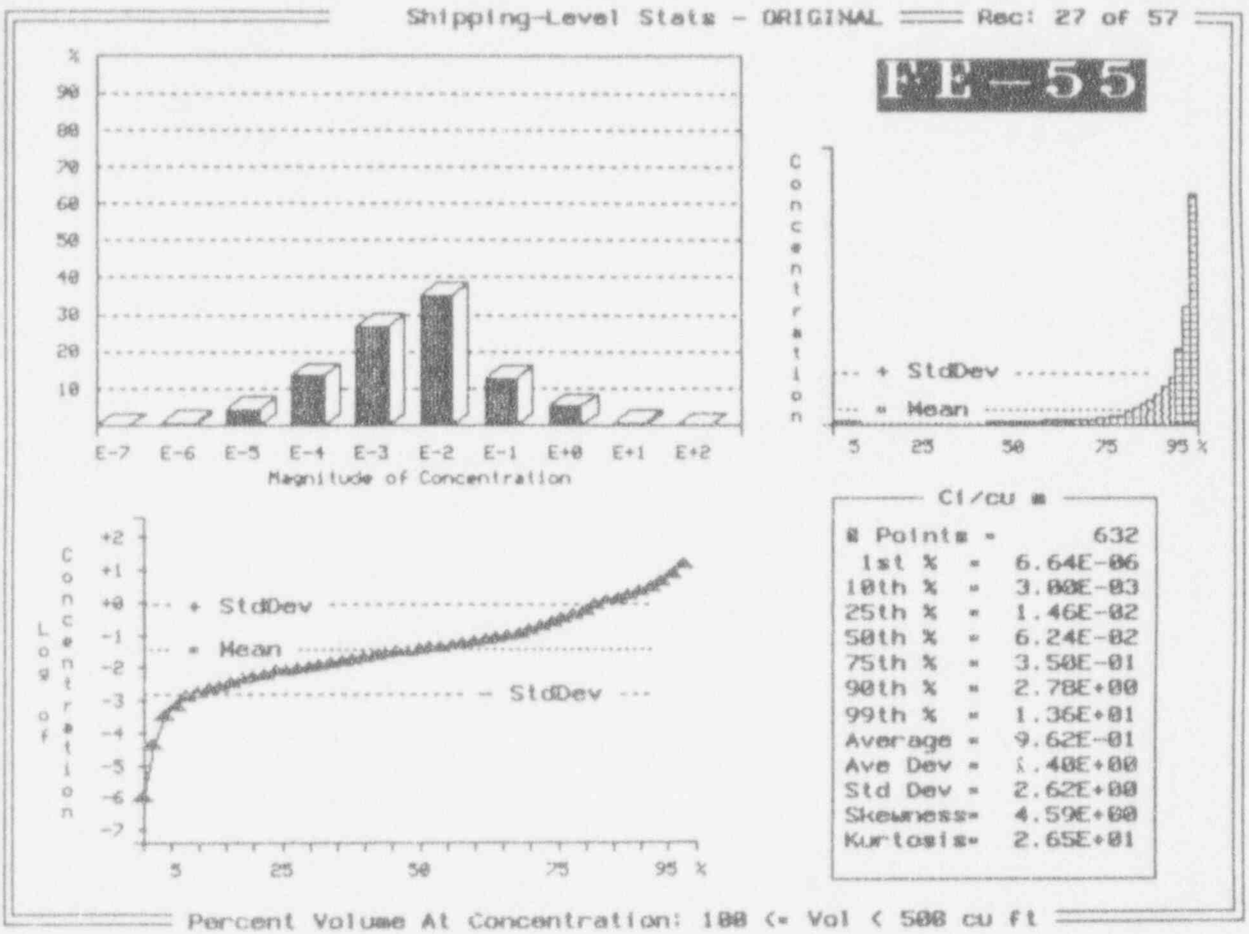


Exhibit 7-2 (Continued)

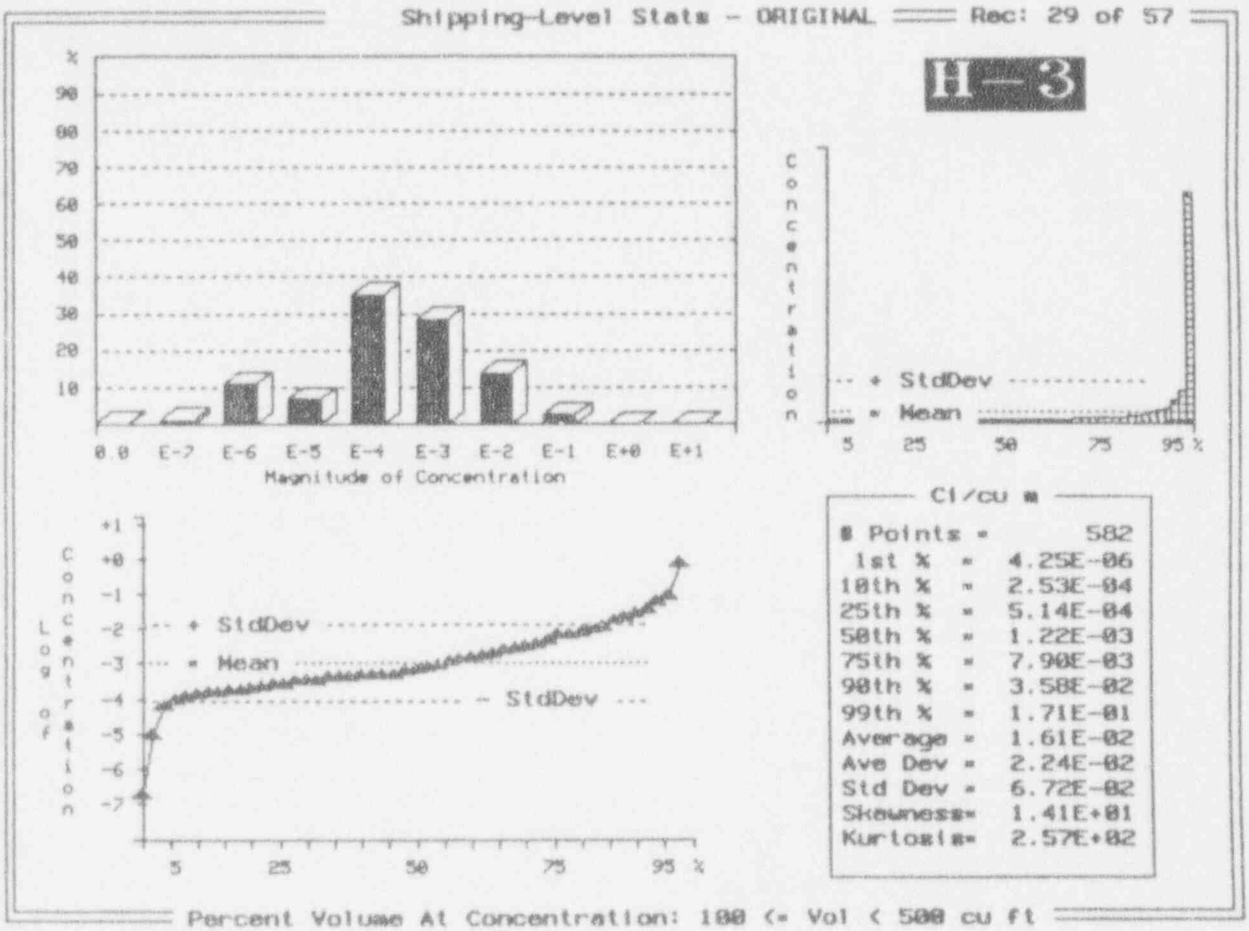


Exhibit 7-2 (Continued)

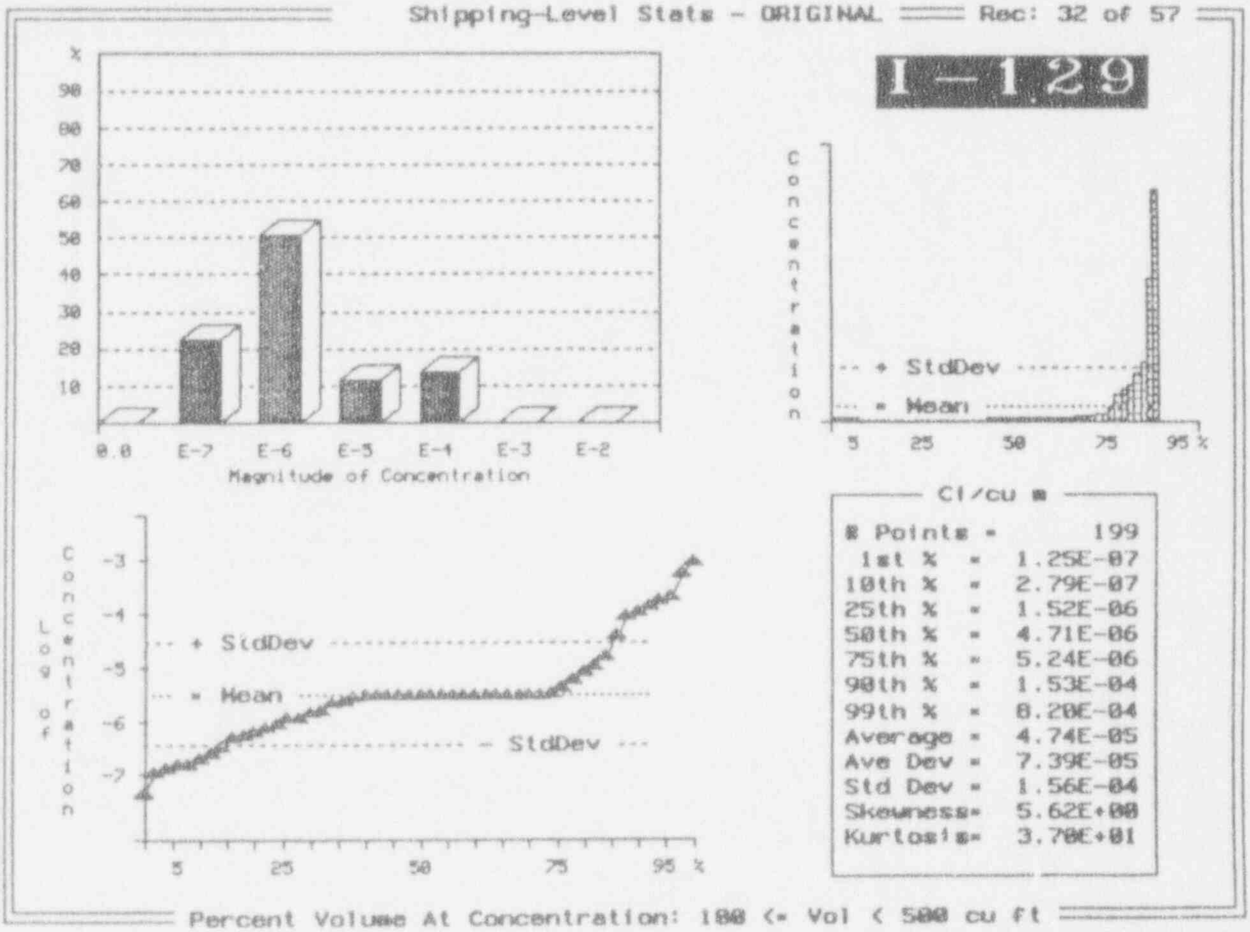


Exhibit 7-2 (Continued)

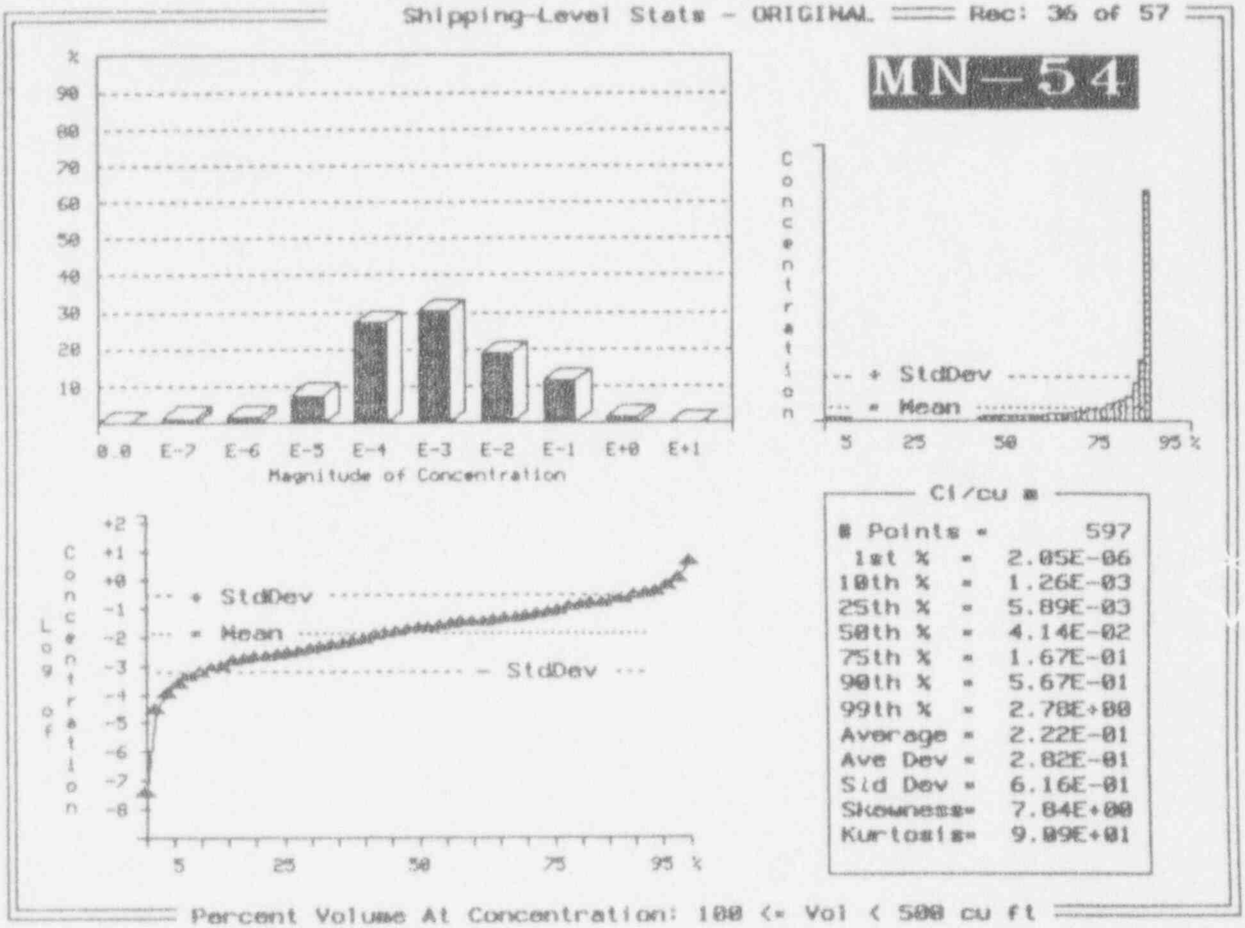


Exhibit 7-2 (Continued)

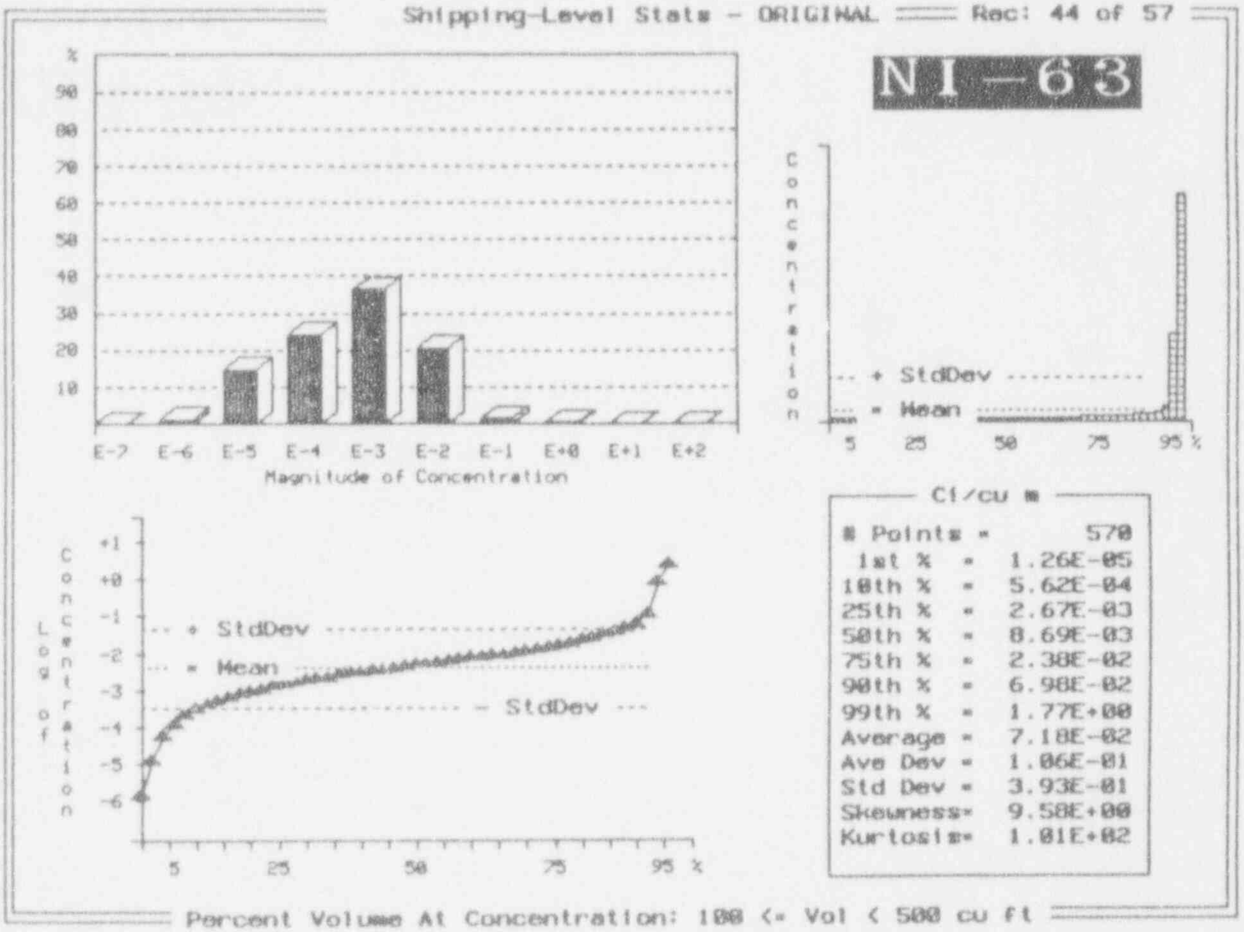
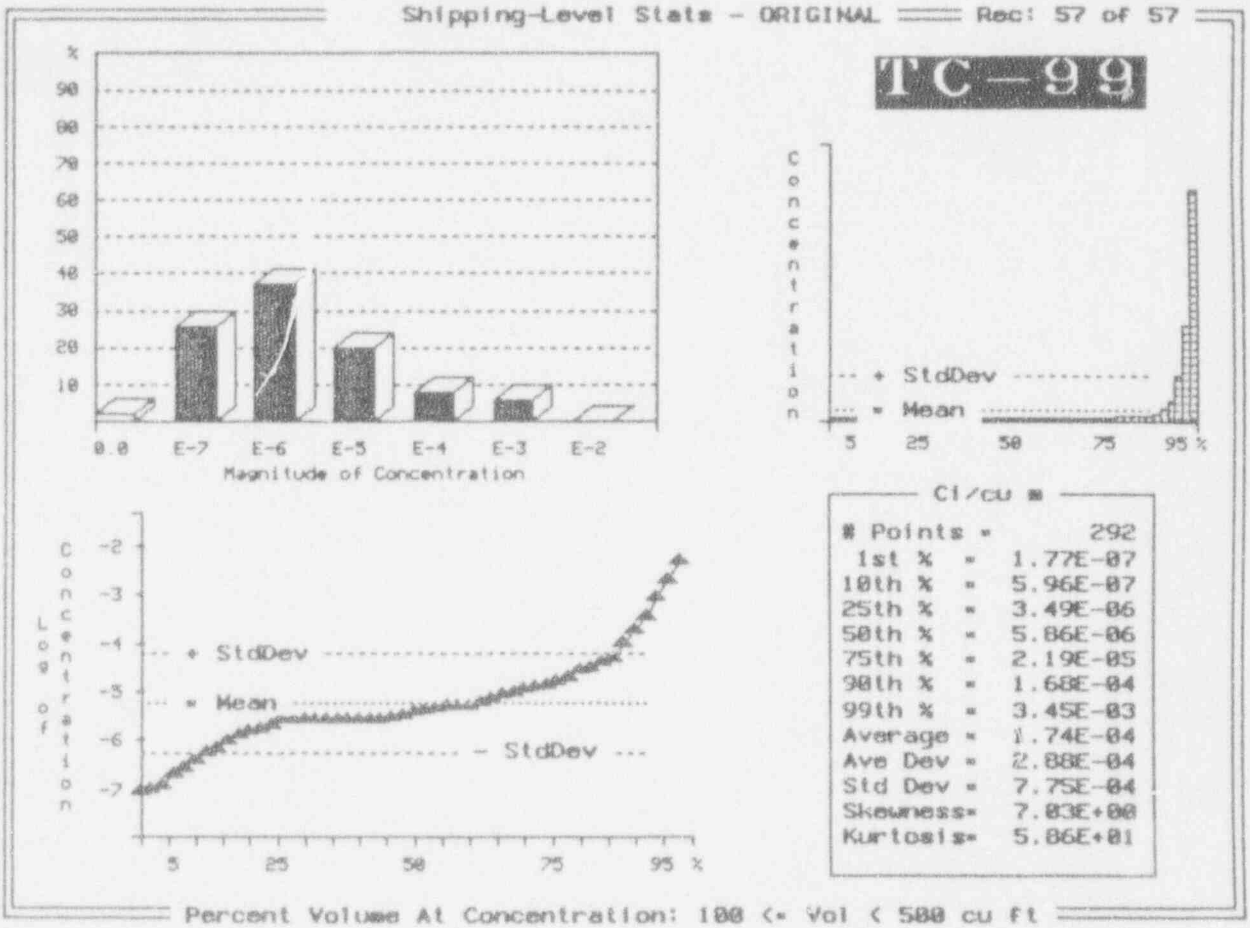


Exhibit 7-2 (Continued)



The following presents a summary of the information provided in Appendix J for selected radionuclides:

Radionuclide Concentration (Ci/m^3) at Percentile

Radionuclide	Barnwell			Richland		
	1	50	99	1	50	99
C-14	1.8E-6	7.0E-4	2.2E-1	2.1E-7	6.7E-4	3.1E-2
Co-60	1.4E-4	6.8E-2	7.9E+0	2.4E-6	4.7E-2	8.8E+0
H-3	8.6E-6	1.5E-3	1.7E-1	4.2E-7	1.5E-3	1.7E-1
I-131	1.4E-5	1.3E-2	1.4E+0	2.1E-7	7.0E-4	2.2E-2
I-129	8.4E-7	8.1E-6	1.3E-3	7.5E-8	3.6E-6	1.2E-3
Pu-239	8.7E-7	3.4E-6	4.5E-4	7.3E-8	4.6E-6	2.7E-4
Sr-90	8.7E-7	1.4E-4	1.5E-2	7.9E-8	1.3E-4	3.9E-2
Tc-99	8.4E-7	1.7E-5	6.3E-3	1.7E-7	4.5E-6	1.2E-3

The data contained in Appendix J reveal that radionuclide concentration distributions at Barnwell and Richland are similar. The Richland results, however, include several radionuclides that do not appear as frequently in the Barnwell data set. The radionuclides that make up over 99% of the waste activity are, however, common to both sites. These radionuclides include C-14, H-3, Cr-51, Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Zn-65, Nb-95, Sr-89, Zr-95, Sb-124, Sb-125, I-131, Cs-134, and Cs-137.

Radionuclide concentrations were observed to vary over seven orders of magnitude, from about 0.1 to 10^6 pCi/g. This distribution is essentially identical to both disposal sites. Most radionuclides, however, fall within a narrower range, i.e., 10^1 to 10^4 pCi/g. In some instances, a few radionuclides are characterized by higher concentrations ranging from 10^6 to 10^7 pCi/g, most notably Cr-51, Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Zn-65, Nb-95, Zr-95, Sn-113, I-131, Cs-134, and Cs-137.

There are no significant differences between the Richland and Barnwell results besides the fact that the Barnwell analysis captured nearly twice (factor of 1.7) as much waste volume as Richland. The resulting aggregate waste concentration (sum of all nuclide activity over total waste volume) for each site compares relatively well with each other, i.e., 0.739 and 0.836 Ci/m^3 for Barnwell and Richland, respectively. Accordingly, it can be assumed that the Richland results characterizing waste forms and radionuclide concentrations at the container level can also be applied to waste disposed at Barnwell. However, there may be some cases when this assumption may not always hold, e.g., when comparing individual power plants.

7.4 Mixed Waste

Mixed waste, characterized by both hazardous chemical and radioactive properties, are generated during various plant activities when chemicals are introduced as cleaning solvents.

Nuclear power plants, however, do not create new products or agents that are chemically hazardous. Plant activities that may result in the generation of mixed waste include routine operations, outage and maintenance, laboratory analyses, and decontamination activities. Furthermore, actual generation rates are highly variable and are dependent upon plant designs and operating characteristics (NUM90, NRC92).

Mixed waste generation rate estimates are based on the results of the 1990 National Profile on Commercially-Generated Low-Level Radioactive Mixed Waste and generic studies because such waste are not being shipped to the disposal sites and, consequently, the low-level database does not contain such information (NRC92, NUM90).

Tables 7-9 and 7-10 summarize the results of the 1990 National Profile for nuclear power plants (NRC92). The results indicate that the major streams include waste oils (34.6%), chlorinated fluorocarbons (27.0%), metals (11.0% for Pb, Hg, Cr, and Cd), and other materials (17.4%) (see Table 7-9). Table 7-10 summarizes the results of the 1990 National Profile by Compact regions and States (NRC92). The results indicate that four Compacts generate about 88 percent of the estimated waste volume. In decreasing order, they are the Southwest, Southeast, Central Midwest, and Appalachian Compacts. The total 1990 mixed waste volume for all regions has been estimated to be 13,625 ft^3. The generation rates were weighted on a national basis to account for facilities which did not respond to the survey and those that were not queried during the survey (NRC92).

In a separate study, NUMARC estimated nearly equal annual mixed waste volumes, 4,250 ft^3 for BWRs and 3,598 ft^3 for PWRs (NUMARC/NESP-006, NUM90). Dry active waste and spent resins were noted to be the dominant mixed waste. Given the uncertainty of these estimates, the difference between BWR and PWR total annual mixed waste generation rates may not be significant.

Other studies conducted by the NRC and Office of Technology Assessment have estimated yet varying waste generation rates, e.g., 1,400 and 10,379 ft^3, respectively (OTA89, NRC85).

7.5 Nuclear Power Plants - Reference Waste Descriptions and Characteristics

The purpose of this section is to identify waste forms, volumes, and radionuclide disposal rates that best typify nuclear utilities. The emphasis in this section is waste volumes and activities per waste generator, as opposed to the previous sections, which address the waste generation rate by the category as a whole.

Table 7-9 Nuclear Utility Mixed Waste Profile - 1990[a]

Waste Stream	Weighted Annual Generation Rate (ft^3/yr)	Percent
Liquid Scintillation Fluids	11	0.08
Waste Oils	4,709	34.6
Chlorinated Organics	50	0.4
Chlorinated Fluorocarbons	3,679	27.0
Other Organics	1,154	8.5
Metals (Pb, Hg, Cr, Cd)	1,497	11.0
Corrosive Materials	156	1.1
Other Materials	2,369	17.4
Total	13,625	(b)

(a) Data extracted from NUREG/CR-5938, Table 4-6 (NRC92).
(b) Result may not add up to 100% due to rounding off.

7.5.1 Waste Streams and Forms

The following are typical waste forms shipped by nuclear power plants:

- compacted and non-compacted dry active waste,
- dry solids,
- waste oils and solvents,
- PWR secondary side resins,
- solidified liquids, and
- sludge and residues from treated and untreated liquid waste.

These waste streams are routinely produced, make up a large fraction of the total waste volume, and are relatively well characterized for their radiological and physical properties.

Table 7-10 Regional Nuclear Utility Mixed Waste Profile - 1990[a]

Compact/State	Estimated Volume (ft^3)
Northwest	31
Rocky Mountain	(b)
Central	238
Midwest	883
Central Midwest	2,679
Southeast	2,757
Northeast	64
Appalachian	1,425
Southwest	5,142
Maine	115
Massachusetts	72
New York	164
Texas	27
Vermont	28
New Hampshire	(b)
Total	13,625

(a) Data extracted from NUREG/CR-5938, Table 4-10 (NRC92).
(b) No data reported.

7.5.2 Waste Volume

In this section, two approaches are used to estimate the volume of waste shipped per waste generator and by Compact and unaffiliated State. The first is based on the data provided in the published literature and the second is derived using the database.

Table 7-11 presents estimates of the annual waste generation rate for nuclear power plants by Compacts and unaffiliated States. The values were derived assuming that the typical PWR and BWR generates 8,200 and 16,800 ft^3 of waste per year, respectively. These results are in general agreement with other estimates (EPR88, EPR89b, DOE90a, DOE90b).

The actual waste generation rates will most likely vary over the next few years, as many facilities will attempt to dispose of as much waste as possible before the end of 1992. January 1993 is the date by which Compacts and unaffiliated States must have in place an operating license for a new low-level waste disposal facility or risk denial of access to currently licensed waste disposal facilities.

The second approach relies on the data compiled in Appendix J. The results, as summarized in Tables 7-12 and 7-13, present averages, ranges, Class A waste generation volumes, and total number of waste generator identification codes by Compact regions or States. The data characterize overall practices from 1986 to 1990. For example, utility waste generators located in the Central Midwest Compact produced 11,630 m^3 of waste over a five year period from 1986 to 1990 (see Table 7-12). The yearly average generation rate is derived by dividing the tabulated waste volume by the assumed cumulative number of reactor operating years for the Compact (based on Table 7-5 data). In this example, the yearly average waste volume is 211 m^3.

In the aggregate, the waste volume shipped per unique generator code from 1986 to 1990 varies over five orders of magnitude, from 0.0142 to 4,180 m^3 (see Table 7-13). At the 50th percentile, the aggregate waste volumes vary from 60.4 to 987 m^3, excluding the Rocky Mountain Compact. Specific case comparisons can be made by Compact regions or States. As can be noted, waste volumes vary significantly among generators as well as among Compact regions. For more details on waste volume distributions, refer to Appendix J figures and tabulations.

Table 7-11 Waste Volume Distribution Among Utility Waste Generators by Regions and States[a]

Compact/State	Average Yearly Waste Volume Generation (m^3) PWR	BWR	Total
Northwest	232	476	708
Central	928	1,428	2,356
Midwest	1,624	1,904	3,528
Central Midwest	696	1,490	2,186
Southeast	3,248	1,904	5,152
Northeast	464	952	1,416
Appalachian	696	1,428	2,124
Southwest	696	0	696
Maine	232	0	232
Massachusetts	181	476	657
New Hampshire	232	0	232
New York	464	952	1,416
Texas	464	0	464
Vermont	0	476	476
Totals:	10,157	11,486	21,643
Plant Average:	232	476	-na-
Region/State			
- Low:	181	476	232
- High:	3,248	1,904	5,152
- Average:	781	1,149	1,546
- Std. Dev.:	837	563	1,424

(a) Compiled assuming geometric means of 232 and 476 m^3 per PWR and BWR, respectively, and number of plant sites in each Compact region or State. Waste generation rates shown in Table 7-5 were used instead for Big Rock Point (62 m^3) and Yankee Rowe (181 m^3) as these two plants have much lower electrical capacity ratings. See text and Tables 7-1 and 7-5 for details. To convert volume to cubic feet, multiply cubic meter by 35.3.

Table 7-12 Waste Volume Distribution Among Utility Waste Generators by Compact Regions and States[a]

Compact/State	No. of Unique Gen. Code	No. of Operating Plants	Waste Volumes - m^3(b) Five-Year Total Vol. All Gen.	Average Yearly Volume
Northwest	3	2	2,841	284
Rocky Mountain(c)	2	(1)	54	14
Central	11	7	5,401	216
Midwest	35	15	9,352	132
Central Midwest	26	13	11,630	211
Southeast	34	33	29,490	188
Northeast	16	8	8,222	211
Appalachian	19	11	13,670	297
Southwest(c)	10	8(1)	6,501	167
Maine	3	1	531	111
Massachusetts	4	2	1,859	186
New Hampshire(c)	-	1	no data	---
New York	14	6	6,037	216
Texas	1	3	107	54
Vermont	1	1	555	111
Total:	179	111	96,250	2,398
- Low:	1	1	54	14
- High:	35	33	29,490	297
- Average:	13	8	6,875	171
- Std. Dev.:	12	9	7,870	80

(a) Compiled from data given in Appendix J for all Class A waste streams. See text for details.

(b) Aggregate and yearly average waste generation rates are rounded off. To convert volume to cubic feet, multiply cubic meter by 35.3.

(c) Rancho Seco (Southwest) and Fort St. Vrain (Rocky Mountain) were included since wastes were shipped for disposal during the reported period. Seabrook (New Hampshire) did not ship waste during the reported period.

Table 7-13 Utility Waste Volume Distributions Among Compact Regions and States[a]

Compact/State	Waste Volume (m^3) at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	3.40E-02	9.87E+02	1.85E+03
Rocky Mountain	1.42E-02	1.42E-02	5.44E+01
Central	4.48E+00	3.60E+02	1.57E+03
Midwest	2.32E-02	6.84E+01	1.10E+03
Central Midwest	2.83E-02	1.54E+02	2.03E+03
Southeast	3.18E-01	1.90E+02	4.18E+03
Northeast	4.48E+00	1.20E+02	2.16E+03
Appalachian	2.97E+00	3.20E+02	2.56E+03
Southwest	2.83E-02	6.90E+01	2.74E+03
Maine	1.59E+01	6.04E+01	4.55E+02
Massachusetts	1.27E+01	2.58E+02	8.14E+02
New York	4.36E-01	2.26E+02	1.20E+03
Texas	1.07E+02	1.07E+02	1.07E+02
Vermont	5.55E+02	5.55E+02	5.55E+02

(a) Compiled from data shown in Appendix J - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. See text for details.

(b) Yearly waste generation distributions may be approximated by dividing above values by five. 1 m^3 = 35.3 cubic feet.

(c) No waste disposed of by Seabrook (New Hampshire) during the reported period.

The results in Table 7-13 should be interpreted with caution since the number of utilities is based on unique identification codes assigned by the disposal sites and not the total number of power plants which actually produced the waste. A review of Table 7-12 indicates that the numbers of assigned waste generator codes are generally different than the numbers of operating plants. For example, the Central Midwest Compact currently has 13 operating plants identified in the low-level database by 26 unique generator codes. For the State of Vermont, however, the number of operating plants and assigned generator code match, indicating that over the reported period waste was shipped to only one disposal site. For the State of Texas, the situation is reversed, there are more operating plants than assigned waste generator codes. This case implies that for some of the plants, waste had not yet been shipped to a disposal site.

7.5.3 Unusual Waste Volumes

Not included in the above estimates are waste volumes associated with unusual plant activities, such as special maintenance, decontamination and decommissioning, and refurbishments associated with plant license renewal. The volume of waste associated with such activities are plant specific and highly variable. The types and volumes of waste associated with such activities are shown in Table 7-6. In addition, a discussion of waste associated with plant license renewal is provided in the "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," NUREG-1437, August 1991. NUREG-1437 estimates that the average incremental increase in all low-level waste associated with refurbishment in support of license renewal would be 91 m^3 per plant per year and 226 m^3 per plant per year over a ten year period for BWRs and PWRs, respectively. The types of waste streams would include dry solids, dry active trash, equipment and components, and possibly core internals.

7.5.4 Extended Fuel Burn-up

Utilities have considered extending fuel burn-up from the current average of 33 to 50 GW-days per metric ton of uranium. The impetus for the higher burn-up is primarily due to more efficient and reliable fuel performance. The associated benefit would include fewer numbers of refueling outages, increased plant capacity factors, and reduced demands for uranium ores. Increased fuel burn-up is thought to have minimal impacts on routine plant operations since plant performance characteristics and specifications would remain unchanged. Waste generation, however, could increase due to higher coolant activity and associated removal of coolant purification filters and resins. Such activities would in turn result in the generation of additional dry active waste. Current estimates indicate that low level generation rates could temporarily increase by about 20 percent (AIF85, NRC88). In the long term, it is believed that further improvement in fuel design will yield better overall performance, which in turn would result in lower waste generation rates.

7.5.5 Radionuclide Disposal Rates Per Waste Generator

Waste activity distributions are shown in Table 7-14. Waste activity levels vary significantly among Compact regions and States. In the aggregate, activity levels vary over six orders of magnitude, from 3.25 mCi to 6,650 Ci. At the 50th percentile, aggregate waste activities also vary significantly by six orders of magnitude across all regions. See Appendix F for more details on waste activity distributions.

The most often cited radionuclides include H-3, C-14, Cr-51, Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Zn-65, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Sb-124, Cs-134, Cs-137, and Ce-144. Other nuclides present at lower concentrations include Co-57, Sr-85, Sr-89, Sr-90, Tc-99, Sb-125, I-129, I-131, I-133, Ba-133, La-140, Ba-140, Pm-147, U-233, U-234, U-235, U-238, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Cm-242, Cm-244, etc.

Most nuclide concentrations tend to cluster over a range from about 10^1 to 10^4 pCi/g for both shipment- and container-level data. In instances where the radionuclide concentrations are significantly higher, the container- and shipment-level data tend to parallel each other. On the low end, the concentrations are confined to a narrower range from about 0.02 to 10^2 pCi/g. This feature is typical of the analyses performed at the shipment level. On the other hand, analyses performed at the container level revealed concentrations starting at a higher range, typically from about 1 to 100 pCi/g. These features indicate that some waste streams are consistently packaged in specific types of containers. The consolidation of waste into a larger volume container tends to reduce overall waste concentrations.

7.6 Geographic Distribution and Demographics of Nuclear Utility Waste Generators

7.6.1 Geographical Distribution

Nuclear utilities are located in urban, suburban, and rural areas. The majority of the nuclear power plants are located east of the Mississippi River. The regions with the highest number of power plants include the Southeast Compact, the Midwest Compact, the Central Midwest Compact, and the Appalachian Compact. The locations of nuclear power plants are identified by city, county, and State. The information contained in Appendix G-1 was extracted from an NRC report (NRC91).

Table 7-14 Utility Waste Activity Distributions Among Compact Regions and States[a]

Compact/State	Waste Activity (Ci) Per Waste Generator at Percentile[b] (Aggregate Practices - 1986 to 1990) Minimum or 1st	50th	Maximum or 99th
Northwest	2.50E-01	7.83E+01	3.21E+03
Rocky Mountain	3.40E-05	3.40E-05	1.04E+02
Central	3.02E+00	2.14E+01	6.45E+02
Midwest	4.00E-02	5.96E+00	1.88E+03
Central Midwest	5.00E-03	9.18E+00	6.65E+03
Southeast	4.16E-04	2.83E+01	1.01E+03
Northeast	1.99E-01	9.11E+00	7.66E+02
Appalachian	3.25E-03	2.82E+01	1.38E+03
Southwest	2.11E-04	6.10E+00	2.70E+02
Maine	4.10E-01	1.31E+00	8.66E+01
Massachusetts	1.25E-01	8.38E-01	4.06E+01
New York	2.12E-02	1.31E+01	3.92E+02
Texas	2.12E+01	2.12E+01	2.12E+01
Vermont	4.83E+01	4.83E+01	4.83E+01

(a) Compiled from data shown in Appendix J - Class A waste only. Data not corrected for generators with access to two or more disposal sites or that are no longer producing waste. No waste was disposed of by Seabrook (New Hampshire) over the reported period. See text for details.

(b) Yearly waste activity distributions may be approximated by dividing above values by five. 1 Ci = 3.7×10^{10} Bq.

7.6.2 Demographics

Population data were obtained from the Bureau of Census based on the 1990 census results (DOC92). The data were sorted to tally population counts by Compact, State, and county. Population data were compiled for each of the nine Compacts and nine unaffiliated States (see Appendix G-2).

8.0 WASTE BROKERS AND PROCESSORS

8.1 Introduction

It is common practice for waste generators to secure commercial services for their disposal needs. Waste brokers supply waste containers, take care of manifesting each shipment, and arrange for waste transportation and disposal. Some brokers provide other types of services, such as waste processing and treatment, consolidation, and decontamination and decommissioning. Such services, however, are not offered by all brokers or processors.

The following subsections present a summary of the type of services routinely provided by waste brokers and processors. In addition, a brief overview is provided of the techniques used by brokers and generators to stabilize or reduce waste volumes and activity levels. This summary is based, in part, on information compiled by the States of New Jersey, Illinois, California (IDN90, NJL90, CDH89). These states were selected since they generate relatively larger amounts of waste and have a large number of licensees within each of the five categories of waste generators. This characterization is not all inclusive, but does provide an overall perspective of the roles and services offered by waste brokers and processors. The locations of waste brokers and processors are identified by city, county, and state (see Appendix G-3).

In reviewing the information presented in this section, the reader is alerted to the fact that the database, on which this characterization is based, incorporates some inherent limitations which must be recognized in order to properly interpret the results. Some of these limitations are associated with waste handling practices, while others are due to differences in how the data are coded and maintained by the disposal sites. Section 2.2 presents a summary of some of the major limitations.

8.2 Waste Broker Services

Most generators that ship low-level waste for disposal rely on the services of waste brokers or processors to make the necessary disposal arrangements. Such services may be used for all or some of the waste. Also included in this category are waste processors, which provide specific waste treatment services. Sometimes, one organization provides both types of services. Generators may find it more cost-effective to secure such services commercially rather than assume those responsibilities.

In general, brokers perform a wide variety of services, including waste handling and packaging, conducting facility inspections, providing regulatory support, decontamination and decommissioning, transportation, handling shipping documents, and securing disposal arrangements with the disposal sites. Waste brokers and processors establish formal programs with generators detailing all applicable regulatory requirements and technical guidelines. Such programs include the following elements:

a) Scope of services and waste disposal fee schedule,
b) Policy statement,
c) Waste receipt and acceptance criteria,
d) Allowable radionuclides and their associated concentration limits for single nuclides and mixtures,
e) Criteria regarding waste class, forms, and chemical and physical properties,
f) Packaging and labelling procedures in accordance with transportation and disposal site requirements,
g) Radiological characterization of each package, external radiation exposure rates and surface contamination levels,
h) Preparation of shipping manifest documents and certification statements,
i) Disposal site use permit and volume allocations,
j) Disposition and accountability of waste forms, volumes, and activity levels.

Most brokers have access to at least one disposal site through the generator's permit. Accordingly, the generator must first secure access to a disposal site and then authorize the broker to ship to that site under its own waste volume allocation and permit. Some brokers and processors, however, have obtained their own waste disposal permits and volume allocations.

Waste volumes handled by brokers vary depending upon the type and number of generators they service. Some brokers provide services primarily to large waste volume generators (e.g., industrial or utilities), while others service primarily smaller institutional facilities (e.g., hospitals, universities, and government institutions).

The services provided by brokers and processors have been evolving primarily as a result of the 1980 Low-Level Radioactive Waste Policy Act (Public Law 96-573, as amended in 1985 under Public Law 99-240). The Act requires that states provide for the disposal of waste generated within their own borders. The legislation encourages states to form multi-state Compacts to develop regional facilities and authorizes each Compact to exclude waste generated by non-member States or Compacts. The Federal law has also established a deadline of January 1, 1993 for States and Compacts to develop their own disposal facilities. After this date, the existing disposal sites may bar access to out-of-region waste generators.

Except for those Compacts that already have operational disposal sites, many Compacts and unaffiliated States are making separate arrangements to develop interim waste storage capabilities. In some instances, arrangements are being secured with waste brokers to provide interim waste storage facilities until a regional disposal site becomes operational. In addition, Compacts and States are refraining from imposing any restrictions on the interstate transfer of waste for treatment purposes (CDH89, DOE90b). Compacts and States would, however, require that treated waste be returned to the state of origin for disposal. This practice would also require generators, brokers, and processors to maintain accurate records of pre- and post-treatment waste volumes and activity levels for proper accountability.

8.3 Waste Processor Services

Most Compacts and States are encouraging the implementation of waste minimization measures involving treatment or processing. Many generators have independently initiated such measures because of increasing disposal costs and restrictions on site volume allocations.

Treatment and processing involve modifying the physical or chemical properties of a specific waste stream. Depending upon the type of waste, such measures yield smaller or stabilized volumes that are often characterized by higher specific activity. The application of a specific treatment method depends upon such factors as the waste stream, radionuclide distribution and concentration, processes that generate the waste, personnel radiation exposures, availability of adequate space and required equipment, and economic considerations. For some generators, it is more effective to have a waste processor provide such services either on-site or elsewhere. A Chicago-based waste broker servicing primarily low volume generators processed in 1989 about 105,000 ft^3 of waste and shipped out 76,000 ft^3 for disposal (DOE90b).

In any case, the selection of a treatment method reflects technical, regulatory, and economic considerations. In some instances, it may be more cost-effective to temporarily set-up a system on site when large volumes of waste are involved. An alternate approach involves shipping waste to a central processing facility when dealing with smaller quantities.

Waste generators use a broad range of waste treatment methods. Table 8-1 summarizes such practices for Illinois waste generators over a 4-year period. Illinois was selected because of the detailed information provided in the annual survey report. The survey results reveal that up to 10 percent of the generators use some type of waste treatment techniques. Those most often

Table 8-1 Waste Treatment and Processing Techniques Used by Various Illinois Waste Generators[a]

Technique	- Percent of Respondents (%) - 1986	1987	1988	1989
Absorption	3	4	2	<1
Compaction (all):	6	1	5	2
Super:	<1	1	1	1
Regular:	6	6	5	2
Baler/Shredder:	<1	1	<1	0
Decontamination:	2	2	10	12
Dewatering:	1	1	3	3
Evaporation:	<1	0	0	<1
Ion-exchange:	2	0	0	0
Filtration:	2	0	<1	0
Incineration:	2	3	3	3
Controlled access:	52	45	46	43
Limit areas:	63	58	58	55
Recycling:	7	7	9	8
Solidification:	2	2	3	3
Waste Sorting				
by nuclide:	42	41	40	39
by half-life:	62	56	57	60
by activity:	33	32	21	28
Use of removable coatings:	2	2	2	2
Use of Substitute methods:	21	17	19	18
Number of survey respondents	259	288	257	249

(a) Extracted from the 1989 Annual Survey Report, Illinois Department of Nuclear Safety (IDN90).

applied include compaction, absorption, and decontamination. It should be noted that the survey results do not provide a breakdown of treatment techniques contracted out to brokers versus those applied by the generator.

Radioactive materials processed by commercial waste processing facilities are not captured in the low-level radioactive database until the resulting waste are disposed of at one of the three disposal sites. For example, a waste generator may ship some components to a facility for decontamination. The resulting amounts of radioactivity and waste volume shipped for disposal may not always be credited to that generator and region (EPR88). The information contained in the shipping manifest does not have any information characterizing such transactions, nor does it indicate what treatment processes were used and what items were returned to the generator or otherwise recycled elsewhere. Consequently, information and data characterizing this intermediate step is not captured by the MIMS database. Waste processors do have such data, but are reluctant to distribute it, as it is considered confidential business information.

A description of some of the most commonly used waste treatment services is summarized below.

Compaction and Supercompaction

Compactors and shredders are used to collapse void spaces within waste articles. Depending upon the compacting pressure and waste form, varying compaction ratios or volume reduction factors can be achieved (EPR88, NRC86a). A conventional compactor will yield a volume reduction factor of about two. A shredder/compactor results in a higher volume reduction factor, typically three to five. A supercompactor, on the other hand, can provide another 2- to 4-fold volume reduction. Compaction is most effective on compressible dry active waste consisting of paper, plastics, cloth, spent HEPA filters, etc.

There are three facilities (operated by Chem-Nuclear, Quadrex, and Scientific Ecology Group) that routinely process waste by supercompaction. These facilities are located in Channahon, IL, and Oak Ridge, TN, respectively (SEG91, CNS91, NJL90). A typical facility includes waste receipt and inspection areas, waste processing and re-packaging areas, and ancillary support areas. A conventional supercompactor can process up to 15 drums per hour or about 70,000 ft^3 per year (CNS91). In 1989, the SEG facility handled 1,230,370 ft^3 of waste, much of which was processed via supercompaction (DOE90b). SEG shipped 314,034 ft^3 of waste from all sources for disposal in 1989.

A supercompactor has also been used as a mobile unit mounted on tractor trailer beds to facilitate transportation (JES89). The hydraulic press and control room are reassembled as a unit once on location. Operating experience with a mobile unit has shown that about 5,000 drums, or about 40,000 ft^3, can be processed yearly (JES89). The use of supercompactors has been considered at the regional level, where it may be cost-effective to set up such a facility to handle larger waste volumes (STO85).

For waste shipped to fixed facilities, large volume generators (e.g., utility) accumulate enough waste (e.g., about 2,000 ft^3) to make a full shipment. Some generators, however, compact the waste even before shipping it out to further reduce demands on storage space and the number of shipments. Supercompaction provides significant volume reduction factors (5 to 7) depending upon the waste and whether it had been initially compacted by the generator.

Decontamination Services

Decontamination usually refers to processes that involve the removal of radioactivity from the surface of equipment, tools, etc. The contaminant may either be fixed or loosely attached to surfaces or contained internally. Decontamination can be performed using various methods, including washing (simple or under high pressure), grinding and polishing, electro-polishing, abrasive cleansing, and solution leaching (using acids or chelating agents, etc.). The resulting liquid is further treated by filtration, ion-exchange, or solidification and disposed as radioactive waste. Decontamination can be performed on site or at a central facility. Decontaminated items may be returned for use, recycling, or disposal without any further radiological restrictions.

Components and items are often shipped by waste generators to specialized facilities that provide decontamination services. The two major decontamination facilities (operated by Alaron and Quadrex) are located in Wampum, PA, and Oak Ridge, TN, respectively (SEG91, NJL90). In some instances, such services are conducted on site. In any case, the process involves removing the radioactive contaminants, returning the article to service or for recycling, and processing the resulting radioactive residues for shipment and disposal. In 1989, Quadrex received 597,000 ft^3 of material for decontamination and shipped 211,250 ft^3 for disposal from all sources. Of the total volume processed by Quadrex, about 90% originates from utilities. Such services are also used by industrial and fuel-cycle facilities.

The types of equipment that are routinely decontaminated include fuel channels, spent-fuel racks, refueling tools, internal components, instrumentation, shipping casks, etc. Decontamination significantly reduces the waste volume that would otherwise require disposal. As opposed to other treatment techniques, waste volume reductions are expressed as recovery rates rather than volume reduction factors. The effectiveness of decontamination methods vary, but recovery rates of 90% or better are not uncommon (EPR84).

Liquid Waste Processing

The major facilities processing liquid waste include Quadrex (Gainesville, FL), Nuclear Sources and Services, (Houston, TX), RAMP Industries (Denver, CO), and Diversified Scientific Services, and Scientific Ecology Group (both of Oak Ridge, TN) (CDH89). Liquid waste processed by these facilities include organic solvents and spent scintillation fluids. The waste consists of xylene, toluene, benzene, acetone, methanol, chlorofluorocarbons, methylethylketone, tetrachloroethylene, oils, chelating agents, etc. It has been estimated that about 103,000 ft^3 of spent liquid scintillation fluids are handled yearly by all waste processors (OTA89). It is also believed that this volume characterizes waste generator practices from all sectors. Quadrex alone processes about 13,000 drums per year, which is the equivalent of about 98,000 ft^3.

Contaminants also include metallic salts in decontamination fluids, chromates, asbestos, acids, resins, etc. Liquid waste is shipped to processing facilities in bulk containers, vials, lab-packs, or absorbed in stabilization media. Upon receipt, such waste is segregated by chemical species and hazardous properties, radionuclide concentrations and half-lives, recycling potential (solvent recovery and extraction), and most effective end-point treatments. Empty containers and crushed vials are washed and sent for disposal as solid waste.

Treatment processes include incineration for destruction or used as a fuel, volume reduction, and immobilization. Only a few facilities are licensed to incinerate, while most have the capabilities to perform volume reduction, segregation, and immobilization. Depending upon the chemical properties of such liquid waste, volume reduction factors can vary significantly, i.e., 1,000 for liquid scintillation fluids and 50 for some organic compounds and sludge residues (CDH89, NRC85). For other types of waste, there is a net increase because the end product is immobilized. Such waste includes metals in solution, incinerator ashes and residues, inorganic salts, acids, resins, etc. The waste volume increase factor can be as high as two (CDH89, NRC85). Typical solidification media include cement, pozzolanic materials, polymers, bitumen, and glass.

For non-combustible material, liquid waste processing includes absorption and solidification. Absorption involves the use of agents that can hold fluids in amounts that are several times their own weights. Various types of agents are routinely being used, e.g., Speedi-Dry, Floor-Dry, etc. Solidification involves mixing a liquid waste and an agent (e.g., cement) either before or after placement in a shipping container. The mixture is then allowed to stabilize and, once solidified, the container is sealed and shipped for disposal. For some categories of waste generators (e.g., nuclear utilities), this treatment process is performed under controlled conditions and subject to quality control procedures to verify that the resulting mix has solidified and is free of standing liquids. Section 2.2 lists a number of absorption and solidification media that are authorized by the Beatty and Richland disposal sites. The use of absorption and solidification agents usually result in a larger waste volume. Volume increase factors may range from two to four, depending upon the type of waste and agents used.

Incineration

Incineration is used for waste that is combustible or that can be incinerated with the introduction of a fuel. The objective is to achieve maximum volume reduction or complete destruction. Some waste streams are introduced in bulk form (e.g., dry active trash), while others may be injected (e.g., oils or organic solvents). Depending upon volatility, contaminants may be retained in off-gas emissions control systems, released out of the stack, or reconcentrated in ash or slag materials. Incineration has been shown to yield varying volume reduction factors, typically 4 to 40 for most types of compressible trash and combustible solid materials and greater than 100 for liquids and most plastics. As with compaction, incineration yields waste residues that are of much higher specific activities than the original waste stream. At times, ash may also have hazardous chemical properties precluding the use of conventional disposal methods.

8.4 Waste Volumes and Activity Levels

Detailed container and shipment-level analyses, using brokered waste data, were not performed for the reasons noted in Section 2.2. All the waste handled by brokers and processors originate from the five categories of waste generators addressed in the previous chapters. Because of these limitations, it is not possible to apportion brokered waste shipments to specific categories of waste generators. This is unfortunate, since brokers handle a significant portion of the nation's low-level waste volume. This section is, therefore, limited to an overview of the volumes and activities shipped by waste brokers and processors.

8.4.1 Waste Shipped to Commercial Disposal Sites

Waste volumes shipped by all waste brokers to each disposal site are shown in Table 8-2. The results summarize aggregate practices from 1986 to late 1990 of all brokered shipments, Class A waste (stable and unstable) only, all waste generators, and all Compact regions and States. The results reveal that the majority of the waste volume and activity is shipped directly by the waste generators. Specifically, from 1986 to 1990, brokered shipments constituted about 22 percent of the volume and four percent of the activity. Table 8-2 also reveals that the quantity of brokered waste varied among the waste disposal sites. Barnwell received both greater waste volumes (13.2%) and activity levels (2.0%).

Richland and Beatty received about half of the waste volumes shipped to Barnwell. When compared to Barnwell, both Richland and Beatty handled approximately a half and a third, respectively, of the total waste activity. Average yearly volumes and activity levels range from 5,700 to 930 m^3 and 8,400 to 3,500 Ci, respectively, over all disposal sites. Table 8-3 presents the percent of the total waste volume and activity shipped by waste brokers from 1986 to 1990 by Compact or State and categories of waste generators. Institutional and industrial generators tend to make greater use of waste broker services than the utility sector. Waste volumes and amounts of activity handled through brokers also varies among regions, from minimal amounts (<0.1%) to all of that produced by a Compact region or State.

Some of the waste shipped by brokers also includes that produced during handling and processing. For example, waste brokers way generate small amounts of waste when sorting, consolidating, and compacting waste. Such waste may include plastics, cloth, paper, protective clothing, radiological samples (e.g., smears, air filters, spent samples), HEPA filters from trash compactors systems, etc. In general, such items are considered to be dry active waste or dry solids. It is, however, suspected that such waste volumes are relatively minimal when compared to those processed for generators. It is generally thought that such waste volumes are insignificant, typically less than 0.1% of the total processed routinely.[4]

Some waste brokers also offer other types of services, e.g., radio-chemical analyses, instrumentation repairs and calibration, radioactive source leak testing, etc. It is not possible to discern from the database what fraction of the waste volume handled by brokers is due to activities performed outside of the range of these services.

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[4] Telecommunication with Mr. Steve Black, Teledyne Isotopes, Inc., and Mr. Jean-Claude Dehmel, S. Cohen & Associates, Inc., May 15, 1991.

Table 8-2 Waste Volume and Activity Levels Shipped by Brokers and Processors - Aggregate Practices for all Class A Waste from 1986 to 1990[a]

Parameter	Barnwell	Richland	Beatty	Total
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):	4.2E+04	1.8E+04	1.9E+04	7.9E+04
% of total:	2.0	0.8	0.9	3.9
Volume (m^3):	2.8E+04	1.4E+04	4.6E+03	4.7E+04
% of total:	13.2	6.4	2.2	22.0
Total weight[b] (kg):	2.8E+07	1.4E+07	4.6E+06	4.7E+07
Average or assumed[c] waste density (g/cm^3):	1.0	0.8	1.1	1.0
Yearly Averages				
Activity (Ci):	8.4E+03	3.5E+03	3.7E+03	---
Volume (m^3):	5.7E+03	2.7E+03	9.3E+02	---
Weight (kg):	5.7E+06	2.7E+06	9.3E+05	---

(a) Totals are for all brokered shipments, Class A waste (stable and unstable), all waste generators, and for all Compacts regions and States from 1986 to late 1990. Data extracted from the database and MIMS on-line service.
(b) Total weights are based on a nominal density of 1.0 g/cm^3 since not all shipments and containers have weight data.
(c) Except for Barnwell, average waste densities reflect only shipments with container data.

Table 8-3 Institutional, Utility, and Industrial Generators Usage Pattern of Waste Brokers from 1986 to 1990[a]

	Waste Volume and Activity Distribution (%)					
	Government		Academic		Medical	
Compact/State	Vol.	Act.	Vol.	Act.	Vol.	Act.
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

Table 8-3 Institutional, Utility, and Industrial Generators Usage Pattern of Waste Brokers from 1986 to 1990[a], Cont'd

Compact/State	Waste Volume and Activity Distribution (%) Utility Volume	Utility Activity	Industrial Volume	Industrial Activity
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	50.4
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 and MIMS on-line service.
(b) No waste was disposed of during the reported period.

Notwithstanding the above information, there still is a great deal of uncertainty about waste volumes routinely handled by processing facilities, although several studies and surveys have been conducted by various organizations (OTA89, DOE90a, CDH89, NJL90, NRC86b, NRC85, NUM90). In its 1989 report, the Congressional Office of Technology Assessment, after reviewing past studies, concluded that some of the uncertainties were in part due to the reluctance or capability of generators to identify waste streams, misinterpretation in overlapping survey results, and the use of inconsistent survey methods (OTA89).

8.4.2 Radionuclides and Radionuclide Concentration Distributions in Brokered Waste

Appendix K provides series of container-level sorts for brokered waste contained in the database. The sorts include compacted and non-compacted dry active waste, dewatered and solidified resins, and sorbed and solidified aqueous liquids. The sorts captured varying numbers of shipment (up to 60) and container (up to 1,909) records, depending on the waste streams. The data are summarized in tables, histograms, and cumulative distribution curves provided in Appendix K.

The results shown in Appendix K indicates that the distribution of radionuclides in brokered waste is not observably different than that present in direct shipments. The radionuclides include H-3, C-14, Na-22, P-32, S-35, Cl-36, Sc-46, Ca-45, Cr-51, Mn-54, Fe-55, Fe-59, Co-57, Co-58, Co-60, Ni-63, Zn-65, Ga-67, Se-75, Rb-86, Sr-85, Kr-85, Sr-90, Nb-95, Tc-99, Tc-99m, Zr-95, Ru-103, Cd-109, Ag-110m, In-111, Sn-113, Sb-124, I-125, I-129, I-131, Ba-133, Xe-133, Cs-134, Cs-137, Ce-141, Ce-144, Gd-153, Tl-201, Po-210, Ra-226, Th-232, U-238, Pu-241, Am-241, and depleted uranium. This listing comprises the majority of the nuclides routinely reported by essentially all waste generator sectors.

The results reveal that concentrations vary routinely over nine orders of magnitude. Mass concentrations vary from about 0.6 pCi/g to 10^8 pCi/g. Except for a few nuclides, most concentrations fall within a narrower range, typically from 10^1 to 10^4 pCi/g. Higher concentrations tend to range from 10^5 to 10^8 pCi/g for H-3, C-14, P-32, S-35, Cr-51, Ni-63, Kr-85, and I-125. On the low end, radionuclide concentrations tend to fall within a limited range of 2 to 10 pCi/g.

8.5 Impact of Waste Processing

Waste treatment usually results in modifying the physical and chemical properties of the waste. In some instances, the resulting end-product may be significantly different in its final state. For example, incineration, evaporation, or solidification yield end-products that have entirely new characteristics.

On the other hand, compaction does not alter the inherent properties of the waste. All waste treatment techniques, however, do change the specific activity and, occasionally, nuclide distributions. Typically, the specific activity of a waste increases proportionally with the volume reduction factor. For solidified or stabilized waste, the specific activity decreases proportionally with the volume increase factor. These relationships may not hold for waste that contains gases and vapors, which may be driven off during treatment.

Treatment can also alter the amounts of radioactivity that may be released from the waste and change its environmental transport characteristics (e.g., accessibility and dispersibility). Some treatments may enhance nuclide solubility (e.g., incineration), while others, such as solidification, may decrease it.

The following presents a comparison of density and radionuclide concentrations in processed and unprocessed waste of the same form. The purpose of this comparison is to determine the degree to which the various processing methods used by brokers or processors result in a discernable change in the specific activity. Table 8-4 presents a comparison of radionuclide concentration distributions for different treatment methods on the following waste:

- compacted versus non-compacted dry active waste,
- dewatered versus solidified resins, and
- sorbed and solidified aqueous liquids.

The data provided in Table 8-4 were extracted from the database for brokered waste (see Appendix K). The results reveal that the average density of solidified waste, as compared to sorbed aqueous liquids, is higher, as anticipated. However, the density of compacted and non-compacted waste is virtually identical. Similarly, there are no significant differences in radionuclide concentrations between the two waste forms. Though one would expect to observe some dissimilarity, the differences are obscured by several factors, all contributing to the variability in radionuclide concentrations.

The results do not offer a true comparative evaluation since the waste, although classified identically, originates from different generators. Another source of uncertainty is how waste is packaged for disposal. Radionuclide concentrations can vary by several orders of magnitude simply because different waste packaging methods are used by the generator. Accordingly, it is not possible to discern subtle variations (i.e., within a factor of ten) in radionuclide concentrations associated with a specific waste treatment method against a backdrop that routinely varies by three to six orders of magnitude.

Table 8-4 Waste Treatment vs Radionuclide Concentrations[a]

Concentration Ranges at Percentile - pCi/g[b]

Waste & Nuclide	-- Not Treated 1st	-- 50th	-- 99th	-- Treated 1st	-- 50th	-- 99th	
Dry active	Non-Compacted			Compacted			Ratio
Average density	0.99 g/cm^3			1.06 g/cm^3			1.1
H-3	4.16E+00	2.47E+03	1.29E+08	3.72E+01	7.66E+03	1.76E+06	3.1
C-14	4.27E+00	1.43E+02	3.33E+05	4.02E+00	9.31E+02	6.01E+05	6.5
P-32	3.94E+00	9.51E+00	5.29E+04	3.58E+00	7.68E+02	9.98E+04	81.0
S-35	7.43E+01	4.15E+03	9.56E+04	7.11E+00	5.38E+03	1.65E+05	1.3
Cr-51	3.72E+00	1.72E+03	7.49E+04	3.50E+00	3.27E+02	3.53E+04	0.2
Co-60	1.11E+01	1.86E+03	5.62E+04	1.85E+00	1.97E+02	1.77E+03	0.1
I-125	4.29E+00	1.87E+03	6.65E+05	1.26E+01	6.52E+03	1.35E+05	3.5
U-238	1.10E+01	1.38E+02	4.87E+02	3.52E+00	5.97E+02	1.13E+04	4.3
						Average	13.8
Liquids	Sorbed Aqueous			Solidified			Ratio
Average density	0.74 g/cm^3			1.34 g/cm^3			1.8
H-3	8.81E+00	1.36E+04	2.91E+06	9.79E+00	4.77E+03	2.36E+06	0.4
C-14	6.95E+00	7.32E+02	8.63E+04	1.06E+01	1.24E+02	1.26E+05	0.2
Na-22	1.40E+01	7.80E+02	2.58E+04	9.53E+00	4.81E+02	1.54E+03	0.6
P-32	4.12E+00	6.24E+02	2.48E+05	1.37E+01	1.64E+02	1.62E+05	0.3
S-35	4.12E+00	3.76E+03	5.55E+05	3.97E+00	3.05E+01	3.66E+04	<0.01
Cr-51	5.06E+00	4.18E+03	2.56E+05	2.61E+01	1.22E+02	8.08E+04	0.03
Ca-45	5.06E+01	1.10E+03	2.03E+04	6.87E+00	2.48E+01	6.98E+03	0.02
Co-57	6.58E+00	1.52E+02	4.79E+03	9.52E+01	7.35E+02	2.94E+03	4.8
I-125	4.66E+00	2.64E+03	4.77E+05	1.37E+01	5.11E+03	3.41E+05	1.9
U-238	1.02E+01	6.93E+02	2.23E+03	2.41E+01	1.19E+02	1.63E+03	0.2
						Average	0.8
Resins	Dewatered			Solidified			Ratio
Average density	1.40 g/cm^3			1.54 g/cm^3			1.1
H-3	3.46E+01	2.13E+02	3.90E+02	3.06E+00	1.66E+03	3.20E+03	7.8
C-14*	0.00E+00	2.20E+01	0.00E+00	0.00E+00	5.02E+02	0.00E+00	22.82
Sc-46*	1.00E+01	1.08E+01	1.16E+01	0.00E+00	1.71E+01	0.00E+00	1.6
Co-60	8.25E+00	8.75E+03	4.73E+04	2.10E+01	1.07E+04	2.42E+04	1.2
Cs-137	1.16E+01	2.24E+03	4.47E+03	1.20E+01	1.36E+01	1.53E+01	<0.01
Ce-141*	9.44E+00	1.03E+01	1.16E+01	0.00E+00	1.71E+01	0.00E+00	1.7
						Average	35.08

(a) Selected radionuclides from brokered shipment and container data to Richland and Beatty for the Illinois (1989) and for all Compact regions and States (1988 to 1990). See text for details. All derived ratios have been rounded off.

(b) Concentrations are based varying number of data points characterizing each range. Nuclides identified with an asterisk(*) are based on a single datum point.

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11. ABSTRACT (200 words or less)

This report describes the physical, chemical, and radiological properties of Class A low-level radioactive waste using data contained in the Manifest Information Management System (MIMS). Other sources of information include reports prepared by the NRC, DOE, low-level waste Compacts and States, and trade industries. The database characterizes low-level waste shipped for disposal from 1986 to 1990. A computer program was developed to analyze the data, with the results summarized in tables, histograms, and cumulative distribution curves presenting radionuclide concentration distributions in Class A waste as a function of waste streams, waste generators, and by regions.

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

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