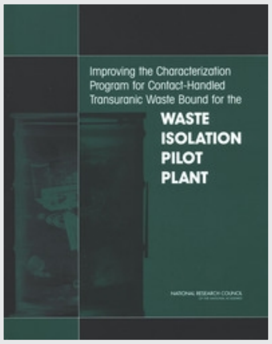

Improving the Characterization Program for Contact-Handled Transuranic Waste Bound for the Waste Isolation Pilot Plant

DETAILS

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Improving the Characterization Program for Contact-Handled Transuranic Waste Bound for the WASTE ISOLATION PILOT PLANT

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Board on Radioactive Waste Management
Division on Earth and Life Studies
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Front cover: Radiography of a 55-gallon drum containing transuranic waste. Real-time radiography is part of DOE's contact-handled transuranic waste characterization program.
Back cover: Contact-handled transuranic waste drums at the Savannah River Site, South Carolina, are stacked in the characterization area waiting to undergo non-destructive assays and headspace gas sampling and analysis.

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Preface

The U.S. Department of Energy (DOE) Carlsbad Field Office asked the National Research Council to provide an independent review of its characterization and characterization-related transportation activities for transuranic (TRU) waste and to recommend ways to improve DOE's transuranic waste management program. To accomplish this, the National Research Council appointed an ad hoc committee of 12 members with expertise in the following disciplines: knowledge of the DOE weapons complex, particularly with respect to TRU waste characterization techniques; hazardous and radioactive waste management regulations; health physics; actinide chemistry; public policy; social sciences; transportation regulations; and risk assessment. The committee's statement of task appears in Sidebar 1.1. Biographical sketches of committee members can be found in Appendix A.

The committee met four times, from October 2002 to May 2003, to complete its information gathering on DOE's characterization program. The committee interacted with DOE and its contractors, waste generator sites, WIPP's primary regulatory agencies (the U.S. Environmental Protection Agency and the New Mexico Environment Department), the New Mexico Environmental Evaluation Group, the Southwest Research and Information Center, citizens' groups, and the public. The committee gathered information on the requirements (and activities to meet these requirements) for characterization and transportation of TRU waste across DOE's complex and on expectations for improving the TRU waste management program.

The committee visited the Savannah River Site to see the waste characterization process first hand and also to see the facility that DOE plans to use as a hub for characterizing TRU waste that will be shipped from small sites throughout the northeastern United States. The committee also visited the Waste Isolation Pilot Plant site, the underground repository for defense-related TRU waste. In addition, the committee went to Santa Fe, New Mexico, to meet with stakeholders and members of the public about the transuranic waste characterization program. Information-gathering meeting agendas and speakers are listed in Appendix B.

ORGANIZATION OF THE REPORT

Chapter 1 provides information about the study, a background description of TRU waste and the Waste Isolation Pilot Plant, and an overview of waste characterization challenges (Section 1.6). Chapter 2 contains information on life cycle, status, and inventories of TRU waste at selected generator sites. Chapter 3 describes the regulatory context for the characterization of contact-handled transuranic waste. The current characterization plan for this waste is described in Chapter 4. In Chapter 5, the committee proposes a structured and quantitative analytical framework to assess the TRU waste characterization program. Findings and recommendations are grouped in Chapter 6. Regulatory requirements in the Land Withdrawal Act, U.S. Environmental Protection Agency, and U.S. Nuclear Regulatory Commission Certifications of Compliance are described in Appendix C. Transportation requirements affecting waste characterization are listed in Appendix D. Appendix E reports the information gathered about worker exposures to radiation related to waste characterization. Appendix F describes elements of risk assessment that would be required to implement the proposed analytical framework.

ACKNOWLEDGMENTS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remains confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

John F.Ahearne, Sigma Xi and Duke University
Eula Bingham, University of Cincinnati
Sue B.Clark, Washington State University
Howard Kunreuther, University of Pennsylvania
Ernest Nieschmidt, Idaho State University
Richard H.Odegaarden, Independent Consultant
Michael T.Ryan, Charleston Southern University
Carol L.Silva, Texas A&M University
Victoria J.Tschinkel, The Nature Conservancy

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by George Hornberger of the University of Virginia. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the National Research Council.

This study would not have been possible without the help of several individuals and organizations. The committee thanks many DOE staff members in the Carlsbad Field Office, in the Office of Environmental Management, and at TRU waste generator sites, including contractors, for their active participation in committee meetings (see Appendix B) and for responding promptly to requests for information. The committee is especially grateful to Roger Nelson, chief scientist at the DOE-Carlsbad Field Office, who served as primary contact for this study and provided outstanding support to the committee's activities; Phil Gregory and Robert Kehrman, for assistance with technical information; and Inés Triay, former manager of the Carlsbad Field Office, for her enthusiasm throughout this study. The committee also expresses its deep appreciation to those who organized site tours, especially Herbert Crapse and Sonny Goldston at the Savannah River Site and Roger Nelson at the Waste Isolation Pilot Plant.

The committee is equally grateful to Steve Zappe of the New Mexico Environment Department and Betsy Forinash of the U.S. Environmental Protection Agency for their input on WIPP's regulatory requirements. Matthew Silva, James Channell, and Ben Walker of the New Mexico Environmental Evaluation Group also provided the committee with helpful technical and historical perspectives on the

characterization of TRU waste. The committee also thanks representatives of public interest groups and the Citizens Advisory Boards for providing their knowledge and perspectives to the committee at meetings (see Appendix B) and in written comments.

Finally, the committee thanks the following National Research Council staff members: Kevin Crowley, who helped the committee understand the larger context of its task; Angela Taylor, who smoothed our way with great organizational skill; Darla Thompson, who provided solid research support and assistance during the study director's maternity leave; and Barbara Pastina, who unflaggingly supported and focused our work. Her knowledge, strong writing skill, balanced judgment, and adeptness in reconciling disparate perspectives were invaluable. The committee is in awe of her deftness in bringing the delightful Giangi into the world and keeping him and us all on an even keel without loosing her own balance.

We add our personal thanks to committee members for their hard work, steady purpose, and good humor.

Susan Wiltshire, *Chair*

Chris Whipple, *Vice Chair*

Committee on Optimizing the Characterization and Transportation of Transuranic Waste Destined for the Waste Isolation Pilot Plant

Contents

Executive Summary

The U.S. Department of Energy (DOE) is responsible for the cleanup of defense-related transuranic waste across its weapons complex. The designated disposal facility for DOE's transuranic waste is the Waste Isolation Pilot Plant (WIPP), a geologic repository near Carlsbad, New Mexico.[1] Transuranic waste can be classified as contact-handled or remote-handled based on the dose rate at the surface of containers (see Sidebar 1.2). This report addresses only the characterization of contact-handled transuranic waste.

Federal and New Mexico laws require that generator sites gather and confirm existing information[2] and, where necessary, acquire additional information on the physical, chemical, and radiological properties of transuranic waste to ensure that the waste contains only materials allowed to be shipped to and disposed of at WIPP. The waste characterization program consists of all characterization activities that are performed at generator sites to satisfy characterization requirements concerning radiological and hazardous properties of the waste set forth by WIPP's regulatory agencies: the U.S. Environmental Protection Agency (EPA), the New Mexico Environment Department (NMED), and the U.S. Nuclear Regulatory Commission (USNRC).

After four years of shipping and disposing transuranic waste in WIPP, DOE has identified waste characterization as one of the most costly and time-consuming parts of the National Transuranic Waste Management Program.[3] According to assessments by DOE, the cost of characterization and certification activities to prepare waste to be shipped to WIPP is estimated to be $3.1 billion, or approximately 16 percent of the $19 billion total costs for the disposal of transuranic waste.[4] A more recent DOE cost estimate based on data from generator sites reported the average cost of characterizing a 55-gallon drum of transuranic waste destined for WIPP to be $3,900 (see Chapter 4).

In light of this assessment, DOE asked the National Research Council for advice on the current waste characterization program[5] for transuranic waste and for recommendations to increase the program's technical soundness, efficiency, cost effectiveness, and safety to workers and the public (the complete task statement is in Sidebar 1.1).

[1]Transuranic waste and WIPP are described in Chapter 1.

[2]Existing information about the waste becomes “acceptable” characterization information through a qualification process described in 40 CFR 194.22(b). This qualified information is then called “Acceptable Knowledge” (see Section 4.3 and Finding 4).

[3]The program is a DOE system-wide approach to the management and disposal of transuranic waste stored and generated throughout the DOE weapons complex. DOE-Carlsbad Field Office manages this program. Information on the program is available on-line at: <http://www.wipp.ws>.

[4]This estimate does not take into account discount rates.

[5]The committee also discusses characterization-related parts of the transportation program.

ES.1 STATEMENT OF THE PROBLEM

The contact-handled transuranic waste characterization program is controversial. DOE, as well as the New Mexico Environmental Evaluation Group and previous National Research Council committees have suggested that some characterization activities may be too extensive, costs too high, and some of the information gathered may not be used to make any decision related to the protection of human health and safety or the environment. Previous National Research Council committees' language is discussed in Sections 1.2 and 5.9. On the other hand, stakeholders in New Mexico have argued that all the current characterization activities are necessary to ensure an adequate level of protection.

DOE has informed the committee of its intention to propose changes to the characterization program to eliminate or modify activities that do not have an impact on human health and safety or the environment. However, DOE did not provide the committee with a formal analysis of the impacts of altering specific characterization activities on costs and risks to the public, workers, or the environment.

The committee observes in Chapter 5 that a structured and quantitative analysis is necessary to determine whether a change to the characterization program is warranted and to justify proposed changes to the regulator (s), state and local officials, and the general public. DOE is responsible for making the policy decision to seek regulatory approval for changes to a particular characterization activity. In Chapter 5, the committee provides the elements and illustrative applications (albeit incomplete) of a proposed structured and quantitative analytical framework that could be used to evaluate changes to specific characterization activities.

ES.2 FINDINGS AND RECOMMENDATIONS

Several general observations underlie the committee's findings and recommendations. First, bringing WIPP to operational status is a significant achievement, given the technical and societal challenges of operating the first and only[6] deep geologic repository for transuranic waste and the complex regulatory environment under which WIPP operates.[7]

During the development of the facility, WIPP has followed a regulatory path typical of many first-of-a-kind facilities with non-routine permits. In developing its transuranic waste characterization program, DOE proposed characterization activities to meet regulatory requirements.[8] The regulatory agencies overseeing WIPP reviewed and approved the inclusion of these characterization activities in WIPP's proposed characterization program. The initial transuranic waste characterization program proposed by DOE to EPA and NMED was based on a conservative interpretation of regulatory requirements.[9]

[6]The Committee recognizes that WIPP is a unique facility for the deep geological disposal of transuranic waste and there are no plans for any other similar facilities in the United States.

[7]The committee identifies technical, societal, and regulatory challenges in Sections 1.5, 2.3, 2.4, and 3.4, respectively.

[8]The committee distinguishes between regulatory requirements (referred to as ”characterization requirements”) and the approach to meet such requirements (“characterization activities”). The committee was not asked to comment on the regulatory requirements themselves or to provide other policy recommendations.

[9]That is, DOE introduced rigorous measures in its waste characterization program, including 100 percent sampling, redundant testing, and extensive confirmation of existing data for the purpose of compensating for the absence of experience in handling this aged waste. Such an approach is favored by regulators in general.

The initial application of conservative requirements is not uncommon for a first-of-a-kind regulated facility, in part because regulators and permittees have no direct operational experience on which to base decisions (see Sidebar 3.2). As operational experience and analyses lead to better understanding, some characterization activities could be modified, reduced, or eliminated and others added. Before such changes can be made, the permittee must demonstrate to the regulator that the proposed changes can provide the required level of safety and meet regulatory requirements. DOE is following this approach for WIPP: requests to modify characterization activities have been submitted to NMED, EPA, and USNRC, the majority of which have been approved (see Section 3.3).

As previously noted, a complete analysis of the benefits and costs of each waste characterization activity is beyond the scope of this study and the committee's capability. In the first finding and recommendation, the committee recommends steps that DOE can take to assess the value of characterization activities based on a structured and quantitative analysis and given the experience gained from four years of operations. In addition, the committee provides five other findings and recommendations that are operational in nature, that do not address specific characterization activities, some of which can be instituted without regulatory approval.

Finding 1: DOE has stated that some characterization activities are too expensive and time consuming and can be modified without increasing risks while reducing characterization time and costs. However, DOE has not presented a systematic analysis to support this argument to the regulators or to the public. Although DOE has performed analyses of many aspects of operations related to WIPP performance, including transportation, the committee could find no studies that explicitly, systematically, and quantitatively link its waste characterization program to risks to the public, workers, or the environment.

Recommendation 1: DOE should use a systematic and quantitative approach to determine the value of the information currently obtained by its waste characterization activities and the impact of changes to them. This approach should also be used to support permit modification requests and communicate with the public. The approach should include analyses of the following types:

- an assessment of the risks of transuranic waste handling, transportation, and disposal activities, including the current characterization activities; and
- an assessment of the impacts—risks, costs, and other impacts, including policy and societal impacts—of changes to the current waste characterization activities.

There are several approaches to achieve this goal. One example is a structured and quantitative analysis based on the value of characterization information collected. In the context of this report, the value of characterization information is determined by how much the information contributes to waste handling, transportation, or disposal decisions. If the information is used to make decisions about waste handling, transportation, or disposal, then it has an impact on the outcome of these decisions (for instance, on reducing risks, uncertainties, costs, or delays), and thus it has value. **On the other hand, if the characterization information is not used in current or future decisions, then it has no impact, and therefore it has no value** (see Chapter 5).

DOE should use such an analytical approach to identify the connections between waste characterization, risks, and costs, and to determine which activities impact these connections. If weak connections are found, the same approach should be used to develop a rationale to request changes from the regulators. These analyses should be published so that outside parties can evaluate the present characterization program and the rationale for proposed changes to the program. Within its constraints of time and information made available, the committee could only point out some of the risks to be included in this risk analysis (see Section 5.3); a complete risk assessment is a major endeavor that the committee was not prepared to undertake.

Based on the information provided by DOE and findings by a previous National Research Council committee, three characterization activities appear to be candidates for the complete application of the analytical framework proposed by the committee:

1. headspace gas sampling and analysis,
2. homogeneous waste sampling and analysis, and
3. visual examination to confirm radiography results.

Finding 2: DOE now has four years of operational experience with the National Transuranic Waste Management program that can be used to improve waste characterization activities.

Recommendation 2: DOE should use its increasing experience base and advances in technology to improve the current transuranic waste characterization program.

The following are examples of potential improvement opportunities together with uses of information from an expanding operational experience base acquired thus far:

- Experience can be used to estimate the extent to which each characterization activity provides information that is: 1) essential to protect health and safety, 2) redundant with other activities or with historical knowledge of the waste, and 3) used to make decisions about waste handling, transportation, or disposal at WIPP. This information is to be used in the structured and quantitative analysis of the characterization program described in Chapter 5.
- Analysis of the characterization data acquired to date along with continuing characterization of increasingly diverse waste streams could identify new opportunities to use statistical sampling (rather than 100 percent of the waste stream) or different methods to confirm Acceptable Knowledge[10] to provide information that would be as protective of health and the environment as the current measurements (see Sections 4.6.2 and 4.6.3).
- Experience provides a basis for ‘know-how' transfer from one generator site to others. The application and sharing of improvements in management methods acquired at generator sites thus far can achieve cost, schedule, and worker dose reduction across the DOE weapons complex (see Section 4.6.1.1).
- Experience allows a better understanding of costs and their variability across the waste inventory and generator sites as well as a better understanding of the relative value of different characterization methods providing similar information (i.e., radiography versus visual examination). Understanding why characterization costs differ significantly from waste stream to waste stream and from site to site could also lead to better cost estimates for future waste streams (see Chapter 5). Changes to the characterization program that would improve the characterization process, together with an expanding operational experience

[10]Acceptable Knowledge is a term used by the EPA that encompasses historical process knowledge and information from previous testing, sampling, and analyses of waste (see Sections 4.1, 4.3 and the Glossary).

base, could help reduce both risks and costs. However, if new and more difficult or complex waste types have to be dealt with in the future, or more stringent cleanup standards are imposed by the regulators, then characterization costs could increase (see Section 5.4).

Finding 3: Current characterization activities are applied generically to all waste types and, with few exceptions, are not tailored to particular waste streams.

Recommendation 3: DOE should propose to its regulators a more flexible waste characterization program that can take into account the properties of different waste streams, allowing more efficient and effective waste characterization operations.

There are categories and subcategories of transuranic waste that may require different methods of characterization depending on whether they are existing wastes, wastes that pose special problems (see Sections 2.3 and 2.4), or to-be-generated wastes. The rationale for this finding is twofold: 1) some waste streams, by the nature of their generation, their physical and chemical properties, and other special circumstances can be shown not to require the entire suite of characterization activities that are currently being carried out; and 2) current characterization methods or technologies are unsuitable for certain waste streams.

Wastes generated in the future (to-be-generated waste) may be better characterized than existing waste, as a result of improvements in management methods, processes, and record keeping. Therefore, some to-be-generated waste streams may not require any, or as much, confirmation of the information collected at the time of waste generation.

Recognizing the differences among waste streams and capitalizing on the opportunities that the improved waste characterization information affords, DOE could propose to its regulators reducing or eliminating some of the current characterization activities for certain waste streams provided it supports its case with a systematic, analytical, and quantitative approach (see Recommendation 1). In addition, DOE should begin detailed planning to address the technical challenges presented by certain waste streams that DOE has not handled to date, as described in Sections 2.3 and 2.4.

Finding 4: DOE is currently using only one of the four methods approved by EPA in 40 CFR 194.22(b) to qualify information as Acceptable Knowledge, namely, confirmation by measurement.[11] Use of the other methods as appropriate could potentially reduce waste handling and costs, increase the efficiency of characterization activities, and extend the use of Acceptable Knowledge for waste generated in the future.

Recommendation 4: DOE should request authorization from its regulators to use all four methods allowed by EPA for qualifying waste information to be used as Acceptable Knowledge.

Continued reliance on the exclusive use of confirmatory testing, which sometimes requires breaching waste containers, becomes an especially important issue for some existing waste streams presenting characterization challenges (see Section 2.3). Furthermore, the characterization of to-be-generated wastes is to be accomplished in accordance with an NMED- and EPA-approved quality assurance program. Therefore,

[11]The four methods to qualify information to be used as Acceptable Knowledge are 1) peer review, 2) use of corroborative evidence, 3) confirmation by measurement, and 4) qualification of a different quality assurance program.

the information collected at the time of waste generation should not require confirmatory measurements in order to be used as Acceptable Knowledge.

Finding 5: Transportation agreements for WIPP shipments have been fashioned over many years of negotiation between DOE and the corridor states. Any changes in the WIPP characterization program could be viewed as undermining these institutional agreements.

Recommendation 5: In addition to working with its regulators, DOE should ensure that corridor states are kept informed of negotiations for changes to the characterization program. Specifically, DOE should communicate effectively with the Western Governors Association, the Southern States Energy Board, and similar groups representing corridor states. DOE should analyze, publish, and present to corridor states' representatives any impact of proposed changes on transportation safety.

Finding 6: Stakeholders have many concerns about WIPP program-related operations. Although specific concerns may vary among people who live near generator sites (risks to site workers, delay in removing waste from generator sites), along transportation corridors (adequacy and reliability of characterization in the event of a transportation accident), or near the WIPP facility (protection of public health over the long term), some concerns are generally shared (the quality of DOE's requests for permit modifications; risks to workers, the public, and the environment; and the adverse effects of external performance pressures on the safety of the cleanup program). Many people who provided comments to the committee expressed concern that any change in characterization requirements or activities could result in decreased protection of worker and public health and/or the environment.

Recommendation 6: DOE should publish clearly written analyses of proposed changes to the characterization program to document that these changes do not adversely affect the protection of worker and public health and/or of the environment. DOE should also provide public access to information about WIPP and its operations, including the WIPP Waste Information System,[12] and communicate interactively with state officials, tribes, public interest groups, and scientific oversight organizations. In this context, the proposed analytical framework could provide a technically defensible approach for supporting changes to the characterization program.

[12]See the Glossary.

1

Introduction

The U.S. Department of Energy (DOE) is responsible for the safe management and disposal of transuranic (TRU) waste produced in defense-related activities and stored at 27 DOE sites across the country.[1] Contact-handled transuranic (CH-TRU) waste is currently being shipped from generator sites and characterization hubs to its final disposal site, the Waste Isolation Pilot Plant (WIPP), in southeastern New Mexico. To obtain authorization to ship TRU waste to WIPP, generator sites must first characterize and certify their waste in compliance with characterization requirements set forth by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED). Additionally, shipping containers[2] must be certified by the U.S. Nuclear Regulatory Commission (USNRC), and shipments must comply with U.S. Department of Transportation (DOT) requirements for hazardous waste. Figure 1.1 shows the location of the ten major TRU waste generator sites and transportation routes to WIPP.

FIGURE 1.1 Location of the ten major transuranic waste generation sites and primary waste transportation routes to the Waste Isolation Pilot Plant. SOURCE: DOE.

[1]Readers who are familiar with background information on transuranic waste and WIPP can skip to Chapter 3.
[2]In this report, "shipping container" refers to a transportation package, typically a TRUPACT-II, while "container" refers to a waste container, typically a 55-gallon drum.

After four years of shipping and disposing TRU waste in WIPP, DOE has identified waste characterization as one of the most costly and time-consuming parts of the National TRU Waste Management Program.[3] According to an assessment by DOE, the cost of characterization and certification activities to prepare waste to be shipped to WIPP (or elsewhere) is estimated to be $3.1 billion, or approximately 16 percent of the $19 billion total life-cycle costs for the disposal of TRU waste (DOE-FSEIS, 1997).[4]

In light of this assessment, DOE asked the National Research Council for scientific and technical advice on opportunities for improving the characterization process and reducing the costs of the CH-TRU waste characterization program. A committee of 12 experts was appointed by the National Research Council and assigned the statement of task in Sidebar 1.1. The committee roster and biographical sketches can be found in Appendix A.

SIDEBAR 1.1 STATEMENT OF TASK

The objectives of this study are: 1) to provide a review of the Department of Energy's program for characterization and characterization-related transportation issues for transuranic waste, and 2) to recommend improvements to increase the program's technical soundness, efficiency, cost-effectiveness, and safety to workers and the public. The study also will address programmatic, policy, and societal impacts of changes in characterization requirements. The study will not address requirements for the characterization of remote-handled transuranic waste or non-technical transportation requirements.

1.1 BOUNDARIES OF THE STATEMENT OF TASK AND STRATEGY TO ADDRESS IT

This report addresses the characterization program for CH-TRU waste; this is the only type of waste currently allowed in WIPP. RH-TRU waste is not allowed for disposal at WIPP because there is no characterization program approved by WIPP regulators for this type of waste. Moreover, the proposed characterization plan for RH-TRU waste was the object of a previous National Research Council report (NRC, 2002). The present report briefly addresses RH-TRU waste as a potential characterization challenge (see Section 2.3.6).

The committee discusses only those transportation requirements that have an impact on characterization activities. It does not address other transportation issues, such as shipment tracking, communication systems, emergency response plans, truck inspections, transportation modes, and so forth.

The first objective of the statement of task is to review DOE's program for transuranic waste characterization. Determining whether there are inefficiencies in the characterization program and what improvements can be made is a complex task. To perform it, a structured and quantitative analysis of characterization activities, coupled with operational experience, can be used to identify which, if any, characterization activities warrant changes. The committee proposes a structured and quantitative analytical framework in Chapter 5 to support its main finding and recommendation (Finding and Recommendation 1).

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[3]The National TRU Waste Management Plan is a DOE system-wide approach to the management and disposal of TRU waste stored and generated throughout the DOE weapons complex (DOE-NTP, 2002). DOE's Carlsbad Field Office manages this program. Information on the program is available at: <http://www.wipp.ws>.

[4]This estimate does not take into account discount rates.

The second objective of the statement of task is addressed in Chapter 6. The committee provides six recommendations that could increase the program's technical soundness, efficiency, cost effectiveness, and safety to workers and the public. These recommendations address the characterization program as whole, not specific characterization activities.

The committee does not recommend changes to specific characterization activities because of the policy nature of such a recommendation. Furthermore, to recommend changes to specific activities would require a systematic and quantitative analysis of risks, costs, and impacts. Such an analysis is beyond the committee's scope (see Finding 1). Nevertheless, the committee provides illustrative applications (albeit incomplete) of the proposed structured and quantitative analysis to three characterization activities that were chosen on the basis of information provided by DOE and findings from a previous National Research Council committee (see Section 5.9).

The report also addresses programmatic, policy, and societal impacts of changes to the characterization program as follows:

- *Programmatic impacts.* Use of experience gained in the first four years of WIPP operations to make programmatic improvements is discussed in Chapter 4. The programmatic impact on risks and costs of changes to characterization activities is discussed in Sections 5.3 and 5.4.
- *Policy impacts.* It is important to recognize the distinction between regulatory requirements (referred to as "characterization requirements") and the approach to meet such requirements ("characterization activities"). The committee does not comment on regulatory requirements themselves because these are prerogatives of DOE's and of the regulatory agencies.' Instead, the committee provides scientific and technical advice on how to improve DOE's waste characterization program within the current policy framework. The policy framework for TRU waste characterization is described in Chapter 3 and Appendices C and D. The committee addresses the policy impact of changes in the characterization program in Section 5.5.
- *Societal impacts.* Societal impacts of changes in the characterization program are discussed in Section 5.6. Potential impacts of changes in the characterization program on corridor states[5] agreements with DOE are also discussed and these societal impacts are the basis for Findings and Recommendations 5 and 6.

The assumption underlying this report is that WIPP must always be in compliance with regulatory requirements. Any improvements to increase the program's technical soundness, efficiency, cost effectiveness, and safety to workers and the public must result in compliance with the regulations. Most changes require regulatory approval. Therefore, the question is whether another characterization activity can meet a given regulatory requirement in a more cost-effective way without reducing the level of protection of human health and the environment. The answer to this question is provided by the application of a structured, quantitative analysis of the value of the information provided by the characterization activity in question.

1.2 ORIGIN OF THIS STUDY

This study builds on two previous National Research Council reports on WIPP: 1) *Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant* (NRC,

[5]Corridor states are those through which TRU waste is expected to be shipped, either to interim DOE sites or to WIPP.

2001), and 2) *Characterization of Remote-Handled Transuranic Waste for the Waste Isolation Pilot Plant* (NRC, 2002). The 2001 report provided a first assessment of characterization activities for CH-TRU waste in the framework of a much broader task on WIPP. The 2002 report addressed characterization activities for remote-handled transuranic (RH-TRU) waste.

Both committees discussed the history of some of the characterization activities for contact-handled transuranic (CH-TRU) waste appearing in the Hazardous Waste Facility Permit (NRC, 2001, 2002, and references therein). Based on DOE analyses of the records of the negotiation process with the State of New Mexico, it appeared that DOE included certain waste characterization activities that went beyond what was required to comply with the requirements in 40 CFR 264. For instance, DOE proposed to NMED to conduct homogeneous waste and headspace gas sampling and analyses on the totality of CH-TRU waste containers to confirm existing information about the waste.[6] Furthermore, a provision for the confirmation of radiography results by visual examination was also included in the 1995 permit application to NMED.

Therefore, the committee that authored the 2001 report recommended (NRC, 2001; page 66):

> DOE should eliminate self-imposed waste characterization requirements that lack a legal or safety basis.[7]

Similarly, the committee that authored the 2002 report on the proposed characterization program for RH-TRU waste recommended (NRC, 2002; page 49):

> DOE should propose only characterization activities that have a technical, health and safety, or regulatory basis.

The present committee uses the characterization activities mentioned in the 2001 report as examples of characterization activities to be re-evaluated using the analytical framework described in Chapter 5 to determine their connection with the protection of human heath and safety (see Section 5.9).

1.3 TRANSURANIC WASTE DEFINED

Transuranic waste is radioactive waste containing radionuclides with atomic numbers greater than that of uranium (Sidebar 1.2 provides information on the definition and classifications of TRU waste). Transuranic waste is generated during the manufacture and reprocessing of plutonium for production reactor fuel and irradiated targets, as well as in various research programs. In recent years, TRU waste has also been generated and collected for disposal through environmental remediation and decontamination and decommissioning operations at DOE sites.

Transuranic waste consists of long-lived alpha-emitting radionuclides, typically plutonium radioisotopes, contaminating items such as protective clothing and gloves, rags, laboratory instruments, gloveboxes, and equipment (see Sidebar 1.2). Other TRU waste in semi-solid form consists primarily of sludge by-products from the chemical separation and recovery of plutonium and other transuranic isotopes. Some TRU waste

[6] For a description of these activities, see Chapter 4.

[7] The word "requirements" in the 2001 report corresponds to "activities" in this report. The term "legal basis" referred to the Land Withdrawal Act, the Resource Conservation and Recovery Act, Titles 40 CFR 191, 40 CFR 194, and 40 CFR 264.

SIDEBAR 1.2 DEFINITION OF TRANSURANIC WASTE AND CLASSIFICATION

The transuranic (TRU) waste category was established in 1970 as the Atomic Energy Commission recognized the need for separation of long-lived, alpha-emitting radionuclides from the low-level waste stream. The TRU elements are so named because they have higher atomic numbers than uranium on the periodic table of the elements. That is, transuranic waste is defined as radioactive waste containing alpha-emitting radionuclides of atomic number greater than 92, half-life[a] greater than 20 years, and activity greater than 100 nanocuries per gram of waste,[b] except for waste that may contain radioisotopes meeting the above definition but is so radioactive that it is designated as high-level waste (e.g., spent nuclear fuel).

The radiation-related health hazard associated with TRU waste is due primarily, but not exclusively, to alpha and gamma radiation. Alpha radiation cannot penetrate human skin but poses a potential health hazard if particles or air containing alpha-emitting radionuclides are inhaled or ingested. Gamma radiation has a higher penetrating power than alpha radiation and poses a potential health hazard if a person is exposed to it without shielding. The alpha-emitting radionuclides of principal concern in TRU waste (their respective half-lives are indicated in parenthesis) are plutonium-238 (87.7 years), plutonium-239 (24,100 years), plutonium-240 (6,560 years), and americium-241 (433 years). Uranium isotopes, such as uranium-233 (159,200 years), uranium-234 (24,600 years), uranium-235 (704 million years), and uranium-238 (4.47 billion years), as well as gamma-emitting radionuclides (non-TRU) may also be present in TRU waste although by themselves they do not meet the TRU waste definition.

Transuranic waste is classified either as contact-handled (CH) or as remote-handled (RH), according to the dose rate measured at the container surface. The dose rate at the container's surface is defined as below 200 mrem per hour for CH-TRU waste; when properly packaged, CH-TRU waste can be handled directly by workers. The dose-rate at the container's surface for RH-TRU waste is defined as greater than 200 mrem. For disposal in WIPP, the surface dose rate from RH-TRU containers is limited to less than 1,000 rem per hour. RH-TRU waste requires heavy shielding and remote-handling equipment. The definition of CH- and RH-TRU waste was a practical one used at DOE sites to separate materials based on operational handling needs. The distinction between CH- and RH-TRU wastes is not directly related to waste disposal hazards or long-term performance of the repository. The high dose rates for RH-TRU waste are due primarily to short-lived radionuclides (half-lives are indicated in parentheses) such as cobalt-60 (5.3 years), strontium-90 (29 years), cesium-137 (30 years), and their progenies. Some of these radioisotopes emit gamma radiation, which can penetrate human skin and the walls of waste containers. Gamma rays are the main radiological health hazard to workers during normal RH-TRU waste handling operations.[c]

Some wastes produce highly penetrating neutron radiation and therefore require special neutron shielding for handling and transportation. Neutrons contribute to the surface dose rate of the waste container and are a factor in deciding whether it is CH- or RH-TRU waste. Other wastes, particularly RH-TRU waste, may emit beta radiation, which is not highly penetrating but generates secondary X-rays (also called *bremsstrahlung* or “braking radiation”) and may require shielding or remote-handling tools.

Transuranic waste is further classified as *mixed* or *non-mixed.* Mixed TRU waste contains both radioactive material regulated under the Atomic Energy Act and hazardous material regulated under the Resource Conservation and Recovery Act, or RCRA (U.S. Congress, 1976). RCRA is a federal law that addresses hazardous waste and is designed to ensure that the generation, transportation, treatment, storage, and disposal of hazardous wastes are conducted in a manner that protects human health and the environment (EPA, 1994). The statutory definition of hazardous waste is provided in Section 1004(5) of RCRA as follows (EPA, 1994; page 1–3):

A solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may 1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or 2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

Hazardous constituents of mixed waste may be volatile organic compounds (e.g., benzene, carbon tetrachloride, and methylene chloride), metals (e.g., chromium, lead, and mercury), and organic sludges, which may contain materials such as polychlorinated biphenyls (PCBs). Examples of TRU mixed wastes include solids or sludges containing solvents used to clean radiation-contaminated areas, contaminated lead shielding, lead-lined gloves and laboratory coats, cloth and paper used to clean up contamination, and contaminated scintillation fluids. For an overview of the Atomic Energy Act and major environmental laws, including RCRA, the reader may refer to *The Nuclear Waste Primer* (League of Women Voters, 1993).

[a]For a definition of half-life, see the Glossary.

[b]While the lower concentration threshold for defining TRU waste is set at 100 nanocuries per gram of alpha-emitting radionuclides per gram of waste, there is no upper concentration threshold. For the first 21,000 drums emplaced in WIPP, the mean concentration of alpha emitters was 16,000 nanocuries per gram and the median concentration was 3,220 nanocuries per gram.

[c]Normal waste handling operation implies that the RH-TRU waste container is not breached and workers are not directly exposed to alpha-emitting radionuclides.

has beta, gamma, or X-ray emissions associated with the TRU radionuclides or with other contaminants of the waste. WIPP can only accept defense-related TRU waste, which is waste produced through activities associated with the U.S. defense nuclear weapons program.

Because of its radiological hazard and the long half-lives of some of its radionuclides, long-term geologic isolation must be provided for TRU waste. In 1992, the U.S. Congress designated the WIPP, a facility near Carlsbad, New Mexico, as the nation's geologic disposal facility for defense-related transuranic waste (U.S. Congress, 1992). The WIPP facility is described in Section 1.4.

The EPA, NMED, and USNRC are the three[8] agencies that regulate WIPP and its related activities. The implementation of regulatory requirements, including those on characterization, is described in permits[9] granted by the regulators: the EPA Certificate of Compliance for WIPP with 40 CFR 194; the NMED Hazardous Waste Facility Permit (HWFP); and the USNRC Certificates of Compliance for containers used to ship TRU

[8]DOE is also a self-regulator for WIPP through internal orders and guidance manuals, as explained in Chapter 3.

[9]In this report, the word “permit” is used in the general sense, addressing both the licensing of radioactive material, transportation containers, or the permitting of hazardous waste facilities.

waste to WIPP (see Chapter 3 and the Glossary). WIPP has to maintain compliance with the EPA, NMED, and USNRC permits at all times to continue operations. Waste characterization activities are designed to meet requirements in these permits.

1.4 THE WASTE ISOLATION PILOT PLANT

The Waste Isolation Pilot Plant, located near Carlsbad, New Mexico, is the nation's defense-related transuranic waste repository, as designated by Congress in the Land Withdrawal Act of 1992 (U.S. Congress, 1992). Legal criteria for WIPP related to TRU waste disposal are discussed in Chapter 3 and Appendix C. The WIPP Land Withdrawal Act transferred control of the WIPP federal land from the Department of the Interior to the Department of Energy. This Act allows the disposal of 175,564 cubic meters of transuranic waste in WIPP, of which 7,080 cubic meters can be RH-TRU waste. The amount of radioactivity in RH-TRU waste is limited to 5.1 million curies.

The WIPP has been under study since the mid-1970s and under construction since January 1981. The facility received the first CH-TRU waste shipment in March 1999 and the first mixed CH-TRU waste shipment in September 2000. To date (December 2003), more than 46,000 drum-equivalents[10] of waste have been emplaced underground and over 2,000 shipments of CH-TRU waste have been sent to WIPP. The five sites that are currently shipping waste to WIPP are the following: Rocky Flats Environmental Technology Site, Idaho National Engineering and Environmental Laboratory, Los Alamos National Laboratory, Savannah River Site, and Hanford Site. Throughout the country there are approximately 27 TRU waste generator sites; most of them are considered “small-quantity” waste generator sites (see Section 2.2 for a complete inventory).

The WIPP disposal area is located about 660 meters below ground in a salt bed, called the Salado Formation (see Figure 1.2). Bedded salt formations have many attributes that make them suitable hosts for a geologic repository. First, large salt formations are found mainly in stable geologic areas with little seismic activity. Second, large salt beds such as the Salado Formation are found only in regions that do not have significant groundwater movement. This deep, relatively dry, underground environment reduces the possibility of waste releases from the repository by natural processes. Third, under the lithostatic pressure at the repository depth, the salt slowly “creeps” to fill voids, thereby encapsulating and immobilizing the waste deep beneath the surface. Analyses indicate that that the mined salt will flow and encapsulate the waste approximately 200 years after closure of the WIPP facility (Knowles and Economy, 2000). A further advantage of salt formations is that they are easily mined without the use of explosives.

The underground waste disposal area in WIPP will consist of eight “panels,” each containing seven rooms. After four years of operation, the first panel has been filled with CH-TRU waste and closed.[11] Emplacement of CH-TRU waste in the second panel began in December 2002. Mining of the third panel began in May 2003. Contact-handled transuranic waste drums and boxes are being stacked in three layers in each room (Figure 1.3). Magnesium oxide is emplaced on top of the waste containers as backfill and to produce an above-neutral pH environment, thereby reducing the solubility of the actinides. In 2001, DOE requested permission from EPA to discontinue the use of small bags of magnesium oxide (“mini-sacks”) to reduce workers exposure to waste. Large

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[10]The term “drum-equivalent” refers to any waste container, such as standard waste boxes or 10-drum overpacks, whose volume is normalized to 55-gallon drums (7.5 cubic feet), the most common waste container.

[11]Three of the rooms in Panel 1 were left vacant because of roof instability.

bags of magnesium oxide ("super-sacks") continue to be emplaced on top of waste stacks. Figure 1.3 shows both mini-sacks and super-sacks.

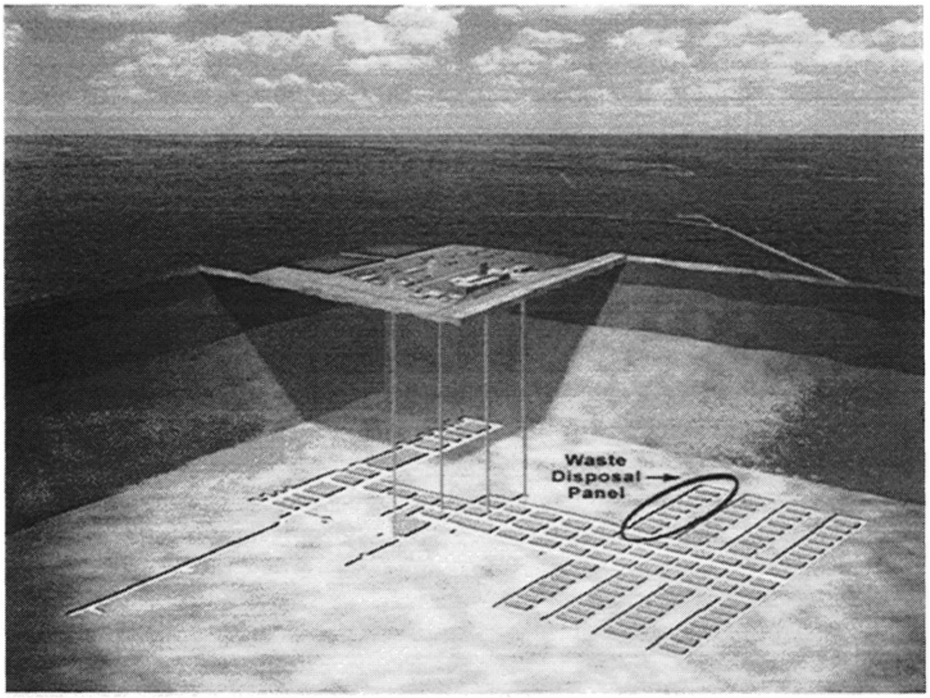

FIGURE 1.2 Schematic representation of the completed Waste Isolation Pilot Plant Facility. The facility will have eight disposal panels, each divided into seven rooms. Only two and part of a third panel have been mined to date (2003). SOURCE: DOE.

1.5 LIFE CYCLE OF TRANSURANIC WASTE

The life cycle of TRU waste, from its generation to its designated final disposal at WIPP, generally[12] consists of the following:

- waste generation or recovery from its current storage location;
- processing and packaging, if necessary;
- characterization and certification;
- loading into shipping containers;
- road transportation to WIPP;
- receipt, unloading, handling, surface interim storage; and
- underground emplacement at WIPP.

The following is a brief description of these steps. As previously mentioned, transuranic waste is already in storage at generator sites or will be generated during ongoing operations or during deactivation and decommissioning activities at DOE sites. TRU waste is currently being stored in metal drums, concrete modules, and metal and wooden boxes. Safe recovery of stored waste can be complex and difficult if containers are difficult to access, if their integrity has been compromised, or if storage records are not available or are deficient.

[12]The life cycle of TRU waste may vary slightly from site to site, depending on the types of waste streams and agreements between DOE and generator sites.

FIGURE 1.3 Contact-handled transuranic waste emplaced in Panel 1. Two types of waste containers are visible: standard waste boxes and 55-gallon drums. Magnesium oxide was placed on top of the waste in large cylindrical containers and on the sides in "mini-sacks" as backfill to ensure an above-neutral pH of the environment and thus reduce the solubility of actinides. Mini-sacks of magnesium oxide are no longer used in the Waste Isolation Pilot Plant. SOURCE: DOE.

Waste processing activities may consist of chemical processing or consolidation of wastes (by compaction or by conversion to a form suitable for disposal at WIPP). For instance, wet sludge must be dried because liquids are prohibited (if more than 1 percent of free liquid by waste volume) in WIPP. In any event, if the waste is not containerized, it must be packaged in accordance with the USNRC Certificate of Compliance as described in the TRUPACT-II Authorized Methods for Payload Control (see Appendix D).

To obtain authorization to ship TRU waste to WIPP, generator sites must first characterize and certify their waste streams[13]—that is, identify them as TRU, determine their physical forms, quantify their chemical constituents, ensure the absence of prohibited items, and provide a certification record. Waste characterization is used to ensure the safe transportation of waste from generator sites to WIPP, to ensure its safe disposal, and to provide a certified record of disposal activities. From a regulatory perspective, all waste sent to WIPP must comply with the WIPP Waste Acceptance Criteria, HWFP, and transportation requirements (see Chapter 3). The waste characterization program for CH-TRU waste is described in Chapter 4. Repackaging of waste may be required in the following instances: 1) the original waste container does not meet transportation requirements, or 2) the waste needs processing to remove prohibited material (see Appendix C).

Waste from small-quantity generator sites can be characterized at other sites having more complete and acceptable characterization capabilities. This is the case, for example, of TRU waste from the Mound Laboratory in Ohio, which is being sent to the Savannah River Site in South Carolina for characterization and certification prior to

[13]A waste stream is defined as waste material generated from a single process or activity or as waste in containers having similar physical, chemical, or radiological characteristics (see the Glossary).

shipment to WIPP (see Appendix E). Waste shipped to other DOE sites for interim storage and characterization need not undergo the characterization for disposal required for waste that is shipped directly to WIPP (see Table D.1). Intersite shipments made prior to shipment to WIPP must, however, comply with transportation requirements and with the receiving site's waste acceptance criteria. These interim characterization sites must ensure proper characterization and certification of all waste shipped to WIPP from their site, including that received from other sites.

Once certified by EPA and NMED, packaged TRU waste is loaded onto USNRC-approved transportation packages, the most common being the TRUPACT-II, and transported to WIPP by road following routes established in accordance with corridor states. The final steps when waste arrives at WIPP consist of checking the shipment for contamination, and if none is found, unloading the waste, storing it temporarily at the surface, and finally emplacing it underground for permanent disposal.[14]

1.6 CHALLENGES OF TRANSURANIC WASTE CHARACTERIZATION

Transuranic waste characterization presents several challenges for DOE's National TRU Waste Management Program, such as the following:

- *High characterization costs and variability in estimates.* On average, characterizing TRU waste to date costs $3,900 per drum (see Section 4.5). There is great variability in cost estimates from site to site due to differences in waste type and volume, different characterization procedures and different methods of reporting costs. Because of such variability, analyzing and comparing characterization costs are complex tasks.
- *Multiple generator sites.* There are 27 TRU waste generator sites across the country. Waste characterization procedures vary (although only slightly) from site to site even though they all comply with the same WIPP Waste Acceptance Criteria and requirements in the WIPP HWFP.
- *Wide variety of waste streams.* DOE identified 569 transuranic waste streams in the Baseline Inventory Report. These vary from heterogeneous debris from deactivation and decommissioning to homogeneous sludges from waste processing. These definitions are, of course, somewhat arbitrary, and the number of waste streams may vary according to the definitions employed.
- *Wide variation in knowledge of waste nature.* Waste streams have been produced at different times, at different sites, and using different processes; furthermore, new streams will be generated in the future. There is a wide range of knowledge concerning the nature of the waste to be characterized. Procedures in place at the site where waste was generated also determine the extent of waste knowledge: records of waste generated in a production facility where operating procedures are codified are generally more detailed than those of waste generated in a research facility. This difference in knowledge of the nature of the waste (also called “Acceptable Knowledge,”[15] see Chapter 4) has an impact on the extent of characterization activities before waste is shipped to WIPP.

[14] A detailed description of the waste disposal process can be found on DOE's WIPP Internet site: <http://www.wipp.ws>.

[15] Acceptable Knowledge is a term used by EPA that encompasses historical process knowledge and information from previous testing, sampling, and analyses of waste. See Section 4.4 and the Glossary.

- *Programmatic uncertainties.* The amount and characteristics of future waste streams may be considerably different from current estimates depending on changes in ongoing programs and in cleanup strategy within DOE. Technological advances will create opportunities to improve waste characterization but their time and impact on the program are difficult to assess.

There are also characterization challenges associated with specific TRU waste streams, as discussed in Section 2.3, as well as regulatory challenges, discussed in Section 3.4.

2

Transuranic Waste Inventories

The first part of this chapter discusses different types of transuranic (TRU) waste in the U.S. Department of Energy (DOE) inventory. Transuranic waste is defined in Chapter 1, Sidebar 1.2. In the second part of this chapter, the committee identifies challenging waste streams that will have to be characterized prior to disposal in the Waste Isolation Pilot Plant (WIPP). Some waste streams without a clear path for disposal may become characterization challenges should they be sent to WIPP.

2.1 EXISTING WASTE AND TO-BE-GENERATED WASTE

The Department of Energy classifies its TRU waste inventories as "legacy" (also called "retrievably stored") waste or "newly generated waste" according to its generation period. Legacy waste was produced after 1970[1] but prior to implementation of the approved contact-handled transuranic (CH-TRU) waste characterization program.[2]

According to DOE's definition, newly generated TRU waste is

- waste yet-to-be generated, sometimes referred to as "projected waste" (see Table 2.1), during ongoing production, research activities, or deactivation and decommissioning activities; or
- existing waste that has to be re-packaged in a suitable form for transportation and disposal.

The Department of Energy's terminology is potentially confusing because newly generated waste refers to both waste that does not yet exist and existing waste (needing repackaging). In this report, the committee uses the terms "to-be-generated" and "existing" waste to distinguish between waste that will be generated in the future and stored waste (whether already packaged or to be re-packaged).

The historical information associated with existing waste must be confirmed (or "qualified") according to procedures set forth by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED), as explained in Chapter 4. For to-be-generated waste, characterization information is collected at the time of waste generation; therefore, if an approved quality assurance plan is in place, the

[1]Prior to 1970, most TRU waste was disposed of by burial in shallow earth trenches using operations similar to those used in low-level waste disposal facilities. In 1970, the Atomic Energy Commission, the predecessor of DOE, determined that radioactive waste contaminated with transuranic isotopes with a concentration of alpha emitters greater than 10 nanocuries per gram of waste should receive greater confinement from the environment. Since that time, TRU waste has been segregated from other types of waste and placed in interim (retrievable) storage until it can be shipped for final disposal in a geologic repository. In 1982, DOE raised the threshold concentration for defining TRU waste to 100 nanocuries per gram. This report does not specifically address pre-1970 buried TRU waste.

[2]EPA approved the waste characterization program for CH-TRU waste in 1998, and the New Mexico Environment Department approved that for mixed CH-TRU waste in 1999.

characterization information should meet the requirements set forth by regulators and does not have to be confirmed. This distinction is important for the discussion about Acceptable Knowledge in Section 4.4.

2.2 TRANSURANIC WASTE INVENTORIES

According to DOE's latest inventory estimates, approximately 190,000 cubic meters of CH-TRU waste and 3,800 cubic meters of remote-handled transuranic (RH-TRU) waste need to be removed from 27 DOE sites across the nation (DOE-NTP, 2002). The TRU waste generator sites are listed in Table 2.1; the 5 largest sites (Hanford, Idaho National Engineering and Environmental Laboratory, Los Alamos National Laboratory, Savannah River, and Rocky Flats Environmental Technology Site[3]) are responsible for 96 percent of stored and projected volumes of CH-TRU waste. The inventory of legacy CH-TRU waste (labeled “stored waste” by DOE in Table 2.1) amounts to approximately 110,000 cubic meters, whereas the volume of to-be-generated waste (labeled “projected” waste) is estimated to be approximately 76,000 cubic meters. Of the 110,000 cubic meters of legacy CH-TRU waste, 15,000 cubic meters have already been emplaced in WIPP, leaving approximately 95,000 cubic meters of legacy waste to be characterized and disposed. Most of the to-be-generated waste will come from sites in Hanford, Idaho, Los Alamos, Savannah River, and Rocky Flats (DOE-TWBIR, 1996). The total radioactivity estimated at the time of WIPP closure in 2035 from CH-TRU waste is approximately 6.4 million curies as shown in Table 2.2.[4]

DOE has programs for the characterization, shipment to, and disposal at WIPP of most existing TRU waste. However, in the future, some “challenging” waste streams may pose characterization difficulties, as described below.

2.3 CHALLENGING WASTE STREAMS DESTINED FOR WIPP

Some of the CH-TRU waste yet to be characterized may present challenges because of a potential for generating flammable gas, oversize containers, fissile isotope content, possible presence of respirable aerosols, prohibited items, high dose rates, or the difficulty of retrieving buried waste. The following description of challenging waste streams was developed from material provided by DOE (Moody and Nelson, 2003) and information gathered in open meetings.

2.3.1 Waste with high potential for generating flammable gas

Heat-generating CH-TRU waste in DOE's inventory presents a potential for generating flammable gas by radiolysis. Heat generated within waste by radioactive decay is primarily an indicator of the alpha-emitting radionuclide content of the waste and is used as a surrogate for actual measurements of flammable gas for transportation purposes. Alpha-emitting material in high concentrations and amounts of high specific radioactivity, such as plutonium-238, can generate flammable gases (e.g., hydrogen) in the presence of a hydrogen source, such as water or plastic, by destroying the chemical bonds that hold the hydrogen atom.[5] Therefore, the concentration of flammable gases generated during shipping must be predicted by calculation and maintained below flammable limits.

[3]The Rocky Flats Technology Environmental Site and the Idaho National Engineering and Environmental Laboratory have priority in shipping TRU waste for disposal at WIPP because of agreements between DOE and the States of Colorado and Idaho, respectively.

[4]DOE plans to release an update of waste inventories by the end of 2003.

[5]Corrosion of steel drums or other reactive metals in the presence of water can also release hydrogen gas over long periods of time.

Table 2.1 Waste Inventory of Major Transuranic Waste Generator Sites

	Contact-Handled Transuranic Waste Volume (cubic meters)				
Site Name and location	Stored[a]	Projected[b]	Total	Disposed actual[c]	To be disposed[d]
ARCO Medical Products Co., Pa.[e]	0.1	0	0.1	0	0
Argonne National Laboratory-East, III.	88.6	169	257.6	0	150.7
Argonne National Laboratory-West, III.	0.1	8.2	8.3	0	0
Babcock & Wilcox-Nuclear Eng. Services, Va.[f]	18.1	0	18.1	0	18.1
Battelle Columbus Laboratories, Ohio	1.9	0	1.9	0	1.9
Bettis Atomic Power Laboratory, Pa.	18.6	0	18.6	0	18.6
Energy Technology Engineering Center, Calif.	2.3	0	2.3	0	2.3
General Electric-Vallecitos Nuclear Center, Calif.[f]	0	20	20	0	20
Hanford Reservation, Wash.	16,124	16,191	32,315	80.4	23,604
Idaho National Engineering and Environmental Laboratory, Idaho	66,742	31,320[g]	98,062	1,019	38,929
Knolls Atomic Power Laboratory, Tenn.[k]	0	0	0	0	0
Knolls Atomic Power Laboratory-Nuclear Fuel Services, Tenn.	30	183	213	0	213
Lawrence Berkeley National Laboratory, Calif.[e]	1.7	0.5	2.2	0	0
Lawrence Livermore National Laboratory, Calif.	294	1,401	1,695	0	920.8
Los Alamos National Laboratory, N.Mex.	9,290	10,816	20,106	271	14,370
Lovelace Respiratory Research Institute, N.Mex.[h]	0.3	14	14.3	0	0
Missouri University Research Reactor, Mo.	1.4	0	1.4	0	1.4
Mound Plant, Ohio	247	0	247	0	0
Nevada Test Site, Nev.	605.2	99.8	705	0	670
Oak Ridge National Laboratory, Tenn.	963	2,060	3,023	0	1,334
Paducah Gaseous Diffusion Plant, Ky.[i]	4.6	0	4.6	0	0
Rocky Flats Environmental Technology Site, Colo.	4,457	10,295	14,752	1,740	13,768
Sandia National Laboratories, N.Mex.	28.5	77	105.5	0	0

Savannah River Site, S.C.	10,848	3,736	14,584	61.7	16,020
Separations Process Research Unit, N.Y.	470	0	470	0	50
U.S. Army Material Command, III.	2.5	0	2.5	0	2.5
West Valley Demonstration Project, N.Y.[e]	77.2	16	93.2	0	0
Total Waste Volumes[j]	110,315.8	76,298.4	186,614.3	3,172.1	110,094.9

[a]The collection and management of waste for the purposes of awaiting processing or disposal capability, in such a manner that does not constitute waste disposal.

[b]The part of the inventory that has not been generated but is currently estimated to be generated at some time in the future.

[c]Volume disposed of at WIPP as of December 31, 2001.

[d]Volume to be disposed of at WIPP. The quantities reflect any volumetric expansion or reduction that would occur during waste processing.

[e]Waste is of commercial origin and does not meet the Land Withdrawal Act (LWA) requirement for disposal at WIPP.

[f]Waste may not be of defense origin; compliance with LWA requirement will need to be demonstrated prior to disposal at WIPP.

[g]The total waste volume reflects some portion that will not be classified as TRU waste, but will be considered alpha-contaminated low-level waste.

[h]Waste from the Lovelace Respiratory Research Institute is shipped to Sandia National Laboratories in New Mexico for subsequent shipment with Sandia's waste to Los Alamos National Laboratory. Lovelace's and Sandia's total waste volumes of 14.3 and 88.5 cubic meters, respectively, are included in the Los Alamos total waste volume.

[i]DOE plans to ship waste from the Paducah Gaseous Diffusion Plant to the Oak Ridge National Laboratory for subsequent shipment to WIPP for disposal. The original Paducah total waste volume of 4.6 cubic meters is included in the ORNL total waste volume as a packaged volume of 11.7 cubic meters.

[j]The total waste volume to be disposed of differs slightly from the 106,387 cubic meters cited in the Revision to the Record of Decision for the DOE's Waste Management Program: Treatment and Storage of Transuranic Waste, published in the Federal Register on December 29, 2000. It should be noted that the total waste volume shown in the table is consistent with the 113,592 cubic meters originally evaluated in the Waste Management Programmatic Environmental Impact Statement (DOE-FSEIS, 1997).

[k]This site only has remote-handled transuranic waste.

SOURCE: DOE-NTP, 2002; Table 3.1–1.

Table 2.2 Estimated Inventory of Major Radionuclides in Contact-Handled Transuranic Waste for Disposal at the Waste Isolation Pilot Plant

Radionuclide	Curies (Ci)
Americium-241	442,000
Curium-244	31,500
Plutonium-238	2,610,000
Plutonium-239	785,000
Plutonium-240	210,000
Plutonium-242	1,170
Total alpha-emitting radionuclides	4,080,000
Barium-137m	7,630
Cesium-137	8,060
Plutonium-241	2,310,000
Strontium-90	6,850
Yttrium-90	6,850
Total beta-emitting radionuclides	2,340,000
Uranium isotopes (232–238)	2,400
Total CH-TRU waste curies	6,420,000

SOURCE: DOE-TWBIR, 1996.

To ensure safe transport of the payload containers in a TRUPACT-II package, the U.S. Nuclear Regulatory Commission (USNRC) has imposed a limit on the concentration of hydrogen within the innermost layer of confinement of a drum or a standard waste box.[6] High-heat waste generally contains plutonium-238, which has a high specific alpha activity or large amounts of plutonium-239.[7] Approximately 2,900 cubic meters, or 2 percent of the volume, of CH-TRU waste is not readily shippable to WIPP because it is calculated to exceed gas generation limits set by the USNRC (this waste is referred to as "high-heat" TRU waste). This includes drums containing plutonium-238 and plutonium-239 wastes that are located principally at four sites: Savannah River Site, Los Alamos National Laboratory, Idaho National Engineering and Environmental Laboratory, and Rocky Flats Environmental Technology Site.

Prior to a recent revision, approximately 2,000 drums containing high concentrations of plutonium at the Los Alamos National Laboratory would have required repackaging into at least 20,000 drums to meet the current heat generation limits of the TRUPACT-II. A revision to the TRUPACT-II Certificate of Compliance provided a means for reducing the shipping period from the Los Alamos National Laboratory to WIPP from 60 days to 5 days, thereby avoiding repackaging about 90 percent of this waste (see

[6]The limit set by the USNRC is 5 percent by volume of hydrogen generated in the drum air during the shipping period.

[7]High heat could also be produced by spontaneously fissioning radionuclides, such as californium-252, and by curium isotopes. However, these radionuclides are present only in trace amounts in CH-TRU waste.

Chapter 3). Inventory analyses at the Savannah River Site indicate that 3,122 drums (650 cubic meters) out of a population of 9,688 drums of debris waste contaminated with plutonium-238 exceed 0.8 grams of plutonium-238 per drum and therefore may exceed heat generation limits for TRUPACT-II as currently packaged. A potential hydrogen generation issue may also impact the shipment of 4,469 cubic meters of plutonium-238 waste in oversized boxes at the Savannah River Site (see below).

Large amounts of plutonium-239 or plutonium-238 in waste pose characterization challenges when waste containers must be opened and the contents visually inspected and repackaged. In particular, according to DOE, plutonium-238 waste poses a challenge because it is liable to form respirable aerosols, both of fine plutonium-238 oxide particles and of organic materials (e.g., plastic bags) that have been in contact with plutonium-238. Because of the processes used to produce them, plutonium-238 wastes tend to be fine particulates (probably less than 2.5-micrometers average diameter) that can spread by alpha recoil or drafts of air. At high concentrations, the high specific heat generation rate of plutonium-238 may cause charring of any organic material that it contacts. Thus, characterization activities that require breaching a waste container (e.g., headspace gas sampling or direct visual examination) may pose a threat of contamination at the generator's site and potential worker exposure even if secondary containment (glovebox) is used. Airborne dispersal of plutonium-238 through the filters may also be possible.

2.3.2 Oversized containers

Approximately 40,000 cubic meters of CH-TRU waste is estimated to exist in oversized containers (e.g., 3.7×2.1×5.5 meters or 12×7×18 feet boxes) that are not transportable in USNRC-approved shipping containers. Current technologies used for non-destructive examination and assay of waste in 55-gallon drums have not been validated on waste stored in oversize containers. This implies that these boxes may have to be opened and the contents handled manually for characterization if non-destructive assay and examination methods do not become available for oversized boxes.[8] Approximately half of the volume of waste in oversize containers is at the Idaho National Engineering and Environmental Laboratory and is destined for on-site size reduction (primarily by compaction) and repackaging at the newly-constructed Advanced Mixed Waste Treatment Facility, when it becomes operational. The rest of the oversized boxes of TRU waste are stored primarily at Hanford, Savannah River Site, Los Alamos National Laboratory, Nevada Test Site, and Lawrence Livermore National Laboratory.

Some wastes in oversized containers are also not shippable due to size and weight constraints on WIPP shipments. Because approximately 95 percent of the oversized waste inventory is packaged in rectangular boxes that are less than 1.5×1.5× 2.4 meters (5×5×8 feet), DOE has initiated the design, testing, and licensing of the TRUPACT-III transportation package in a configuration that could easily accommodate a box of this size without the need to repackage (see Chapter 3). According to DOE, the TRUPACT-III configuration will exceed the allowable highway shipping weights so that exemptions from USNRC requirements may be needed.

2.3.3 Fissile isotope content

There are limits on the quantity of fissionable materials in shipping containers to prevent criticality. These limits may restrict the average fissile gram equivalent per payload container and result in additional shipments. This is the case for 56 drums

[8] DOE is also currently planning a request for proposals to develop and demonstrate non-destructive assay and examination methods for oversize containers.

(approximately 12 cubic meters) out of a population of 16,410 drums of debris waste at the Savannah River Site. This waste is contaminated with plutonium-239 and may require repackaging in order to meet current TRUPACT-II limits (200 grams per drum). These characterization challenges are the same as those for high-heat waste, namely potential worker exposure to radiation or contamination during repackaging.

2.3.4 Legacy waste generated in research laboratories

Although most of CH-TRU waste was generated at "production" sites, some waste streams originated from laboratories such as the Idaho National Engineering and Environmental Laboratory that processed spent fuel and conducted related research. Records of these small, specialized waste streams from research operations are not as complete as those kept at production sites, where the waste processes were well established and good-quality records were usually maintained. Moreover, some of this laboratory waste is potentially more hazardous than production waste because of its experimental nature.

2.3.5 Prohibited items

Some wastes, such as oil and solvent immobilization system (OASIS) waste and other organic waste sludges, sealed sources, or heat-sealed bags greater than 4 liters in volume, cannot be shipped to WIPP due to the presence of prohibited items.

2.3.5.1 OASIS and other organic sludge wastes

OASIS wastes are organic sludge wastes that resulted when spent cutting fluids and solvents from plutonium machining operations were solidified with gypsum cement. These wastes will be difficult to radiograph, and visual examination would be meaningless. Further, non-destructive assay may be rendered more difficult by the presence of cement. Part of the OASIS waste at the Rocky Flats Environmental Technology Site was solidified with gypsum cement and shipped to the Idaho National Engineering and Environmental Laboratory in the 1970s. Subsequently, the Rocky Flats Environmental Technology Site generated additional drums from the same process and stored the waste on site. There are approximately 2,200 cubic meters of organic sludge at the Rocky Flats Environmental Technology Site and Idaho National Engineering and Environmental Laboratory combined (Moody et al., 2003). Headspace gas samples from these waste streams at the Rocky Flats Environmental Technology Site and the Idaho National Engineering and Environmental Laboratory show that most of this waste fails transportation requirements for flammable gases, mainly hydrogen, and/or fails gas generation testing due to total gas generated.

2.3.5.2 Sealed sources

More than 5,000 sealed radioactive sources,[9] with an eventual projection of 18,000 to be recovered, have been catalogued at Los Alamos National Laboratory. Los Alamos National Laboratory developed a packaging configuration for a variety of waste streams, including sealed sources, called the "pipe component." This consists of a robust stainless steel inner cylinder overpacked with a standard 55-gallon drum, with a range of shielding options depending on the nature of the radioactive materials. Characterization requirements for these drums are not yet finalized. However, if headspace gas analysis must be performed on the pipe component, personnel exposure may result. The sealed sources themselves are not a source of flammable gases. Although not a characterization issue, a further challenge presented by this waste is that

[9]Some of the sealed sources could be classified as RH-TRU waste.

only 5 percent (equivalent to approximately 100 drums of TRU waste) comes from defense applications. Hence, the remaining 95 percent cannot be disposed at WIPP without a change in federal law to permit the disposal of non-defense TRU waste.

2.3.5.3 Wastes containing heat-sealed bags

Any sealed container greater than 4 liters inside a waste drum is considered a prohibited item and precluded from shipment to and disposal at WIPP. Real-time radiography, one of the characterization methods used to detect prohibited items in waste drums, cannot detect heat seals. Therefore, the safety concern is that, if the sealed bag cannot be removed or breached before it is shipped to WIPP, hydrogen may accumulate. Several sites historically employed heat-sealed bags in plutonium operations. The Hanford Site identified 3,000 drums containing such bags.

2.3.6 Remote-handled transuranic waste 10

Characterizing RH-TRU waste is challenging because of the higher surface dose rates of waste containers. When working with RH-TRU waste, additional radiation safety measures will be required to maintain worker doses as low as reasonably achievable (ALARA). Although RH-TRU comprises only 2 to 4 percent by volume of total TRU waste, it represents 13.5 percent by radioactivity at time of emplacement. Up to 5 percent by volume of RH-TRU waste is permitted to have a surface dose rate as high as 1,000 rem per hour, and 95 percent may have between 200 mrem and 100 mrem per hour.

Remote-handled TRU waste is currently not authorized for disposal at WIPP because EPA and NMED have not approved a characterization plan for this type of waste.[11] EPA, NMED, the New Mexico Environmental Evaluation Group, and a previous National Research Council committee have expressed concerns that characterization methods used for CH-TRU waste, such as real-time radiography, non-destructive assay, or non-destructive examination methods, may not be effective in the presence of the high-gamma, neutron, bremsstrahlung, or X-ray fields created by RH-TRU waste (EEG, 1994; EPA, 1998; NMED, 1999; NRC, 2002). RH-TRU waste exists as a number of specialized, small-scale waste streams that may call for new equipment or for procedures that differ significantly from those used in the usual waste characterization processes.

Remote-handled TRU waste with a surface dose rate greater than 1,000 rem per hour may also become a challenge in the future. The WIPP Land Withdrawal Act established an upper limit for the surface dose rate for RH waste of 1,000 rem per hour; therefore, any TRU waste that produces more than 1,000 rem per hour cannot be sent to WIPP. To date, there has been no official inventory of the quantity of RH-TRU waste falling into this category.

[10] Although RH-TRU waste characterization is outside this study's statement of task, it is briefly discussed in this section as a potential characterization challenge.

[11] DOE is interacting with NMED and EPA to submit a new characterization plan for RH-TRU waste. In June 2002, DOE submitted a permit modification request to NMED to receive and dispose of RH-TRU waste in WIPP. In May 2003, DOE submitted a revised permit modification request in response to NMED's notice of deficiency (NMED, 2003a). NMED is currently reviewing the revised proposal. In April 2003, DOE submitted a formal proposal to EPA to modify WIPP's Certification and, in September 2003, a revised proposal was submitted in response to EPA's comments. EPA is currently reviewing the revised proposal.

2.4 CHALLENGING WASTE STREAMS WITHOUT A CLEAR PATH FOR DISPOSAL

In its National TRU Waste Management Program, DOE recognizes that there are about 9,600 cubic meters of TRU waste without a current plan for disposal (DOE-NTP, 2002). These are wastes contaminated with reactive or corrosive substances and TRU waste generated from non-defense activities. The committee also identifies TRU waste buried prior to 1970 as a challenging waste stream.

DOE estimates that 126,000 cubic meters of TRU wastes were disposed by shallow-land burial at various DOE sites, particularly at the Idaho National Engineering and Environmental Laboratory, prior to 1970. No decision has been made whether to exhume the wastes for deep geologic burial at WIPP or any other site (DOE-EM, 2000). If so, characterization would be required before disposal.[12]

[12]The New Mexico Environmental Evaluation Group has recently released a report concerning buried TRU waste, including future characterization needs (EEG, 2003a).

3

Regulatory and Policy Framework for Waste Characterization

This chapter discusses the regulatory and policy framework for the characterization of contact-handled transuranic (CH-TRU) waste destined for the Waste Isolation Pilot Plant (WIPP). A discussion of the regulatory and oversight bodies for WIPP, as well as the primary regulatory documents, is provided in this chapter and in Appendices C and D. Amendments to the authorizing basis documents,[1] along with the processes for requesting and approving changes, are also discussed here. Finally, regulatory challenges for WIPP and other first-of-a-kind facilities[2] conclude this chapter.

3.1 REGULATORY BODIES FOR WIPP

The U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) are the only agencies, other than the U.S. Department of Energy (DOE), with direct regulatory authority over WIPP, but a number of other federal and state regulatory bodies are involved in WIPP activities, as shown in Table C.1. Of these agencies, only EPA and NMED have jurisdiction over waste characterization operations. The U.S. Nuclear Regulatory Commission (USNRC) has regulatory authority over TRU waste shipping containers.

With the exception of the EPA standards for disposal (40 CFR 191), the DOE self-regulates its activities involving radiation (10 CFR 835, DOE Orders, and various internal guidance documents). DOE is also responsible for ensuring that transportation regulations for hazardous waste are met. DOE interacts with corridor states and Tribal Nations on issues relating to TRU waste transportation planning and emergency response through cooperative agreements. Corridor states are represented by the Western Governors' Association (WGA; see Sidebar 3.1), the Council of State Governments-Midwestern Radioactive Materials Transportation Project, and the Southern States Energy Board. These cooperative agreements mandate regular meetings in which radiological health, emergency management, and transportation officials receive information on TRU waste program activities and discuss planning and implementation concerns with DOE representatives.

Although it is not a regulator, the New Mexico Environmental Evaluation Group has had an oversight role since 1978 to help ensure the protection of public health and safety and the environment. The roles of this oversight group include the review and evaluation of all proposed standards; reviews of transportation information; audits of

[1]These documents are the New Mexico Hazardous Waste Facility Permit, the U.S. Environmental Protection Agency Certificate of Compliance for WIPP and U.S. Nuclear Regulatory Commission Certificate of Compliance for the shipping container.

[2]The Committee recognizes that WIPP is a unique facility for the deep geological disposal of transuranic waste and there are no plans for any other similar facilities in the United States.

characterization procedures at the generating sites; and analyses of water, soil, and organic samples jointly obtained with WIPP environmental monitoring programs.

3.2 MAIN REGULATORY DOCUMENTS

To continue disposal operations, WIPP must show continued compliance with regulatory constraints derived from the following laws and regulations: Land Withdrawal Act (as amended), 40 CFR 191, 40 CFR 194, and 40 CFR 264.[3] The CH-TRU waste characterization program consists of characterization activities to address requirements in the above laws and regulations. The characterization activities appear in the following WIPP authorization basis documents:

- EPA Certificate of Compliance for WIPP,
- NMED Hazardous Waste Facility Permit (HWFP), and
- USNRC Certificate of Compliance for shipping containers, which also addresses U.S. Department of Transportation regulations.

Characterization requirements are generally compiled in the Waste Acceptance Criteria, although not all requirements mentioned in the HWFP are listed. The Land Withdrawal Act, authorization basis documents, and Waste Acceptance Criteria are described briefly below; additional information is provided in Appendix C.

3.2.1 Land Withdrawal Act

The Land Withdrawal Act, Public Law 102–579, is the guiding legislation for WIPP (U.S. Congress, 1992). In this Act, Congress established the scope and legal criteria for the WIPP facility and withdrew 41.6 square kilometers (16 square miles) of land from the U.S. Department of Interior in favor of DOE use for “entry, appropriation, and disposal.” The Land Withdrawal Act also assigned EPA regulatory authority over TRU radioactive waste standards and final disposal regulations. The Land Withdrawal Act includes many other requirements and provisions pertaining to the protection of public health and the environment. Details of characterization-related requirements of the Land Withdrawal Act are provided in Appendix C.

3.2.2 EPA Certificate of Compliance

In accordance with the Land Withdrawal Act, in 1996 EPA promulgated criteria (40 CFR 194) for the certification and recertification of the Waste Isolation Pilot Plant's compliance with 40 CFR 191.[4] In 1998, EPA declared WIPP to be in compliance with its disposal regulations and granted the facility a certificate of compliance, herein called “EPA Certification.” EPA regulates public exposure to radiation at the land withdrawal boundaries resulting from the management and storage of TRU waste at WIPP during its operational period (nominally lasting until 2033) and regulates radioactivity releases into the environment up to 10,000 years after repository closure. The EPA Certification must be reviewed every five years. Details of characterization-related requirements in the EPA Certification are provided in Appendix C.

3.2.3 NMED Hazardous Waste Facility Permit

The NMED issued the WIPP HWFP in 1999 to allow DOE to dispose of TRU mixed waste in WIPP in compliance with the Resource Conservation and Recovery Act

[3]For additional information on these laws and regulations, see the Glossary.

[4]Title 40 CFR 191 lists the standards for management and disposal of spent nuclear fuel, high-level waste, and transuranic waste (see the Glossary).

(RCRA), the New Mexico Hazardous Waste Act (HWA), and EPA standards for mixed waste (40 CFR 264).[5] The primary purpose of this permit is to regulate the design, construction, maintenance, operation, and closure of WIPP in a manner that will ensure protection of human health and the environment from the hazardous components of waste. NMED regulates the releases[6] of non-radiological hazardous constituents during the operational phase and for a nominal 30-years following repository closure. The HWFP contains a Waste Analysis Plan that describes waste characterization activities to be performed at generator sites before waste is shipped to WIPP. Waste characterization requirements in the Waste Analysis Plan are intended to provide a detailed chemical and physical analysis of a representative sample of the waste in accordance with RCRA. The HWFP must be renewed every 10 years. Details of characterization-related requirements in the HWFP are provided in Appendix C.

3.2.4 USNRC Certificate of Compliance for transportation packages

The USNRC regulates the packaging for transportation of radioactive waste. Regulatory requirements for transportation of hazardous, including radioactive, waste are promulgated in 10 CFR 71. Each shipping container design destined for WIPP must obtain a USNRC certificate of compliance with the requirements in 10 CFR 71. To certify a package design, DOE must submit a Safety Analysis Report for transportation packages to the USNRC. The Safety Analysis Report describes the physical characteristics of the package, the quality assurance program for package design, and the results of normal conditions testing and incident or accident conditions testing. The USNRC issued Type B (see the Glossary) certificates of compliance for the TRUPACT-II transportation packages. Requirements for authorized contents in the TRUPACT-II Certificate of Compliance are implemented in TRUPACT-II Authorized Methods of Payload Control (TRAMPAC). Other USNRC-approved shipping containers are the HalfPACT and the RH 72-B, the latter for transportation of remote-handled transuranic (RH-TRU) waste. Details of characterization-related requirements for transportation packages are provided in Appendix D.

3.2.5 Waste Acceptance Criteria

The Waste Acceptance Criteria is a document written by DOE to consolidate all of the existing acceptance criteria and ensure uniformity in TRU waste documentation, transportation, handling, and disposal activities at WIPP. The Waste Acceptance Criteria set limits and criteria on the physical aspects, radiological aspects, quantity, and chemical composition of TRU waste. For example, the criteria include information on the following parameters: gas generation, waste immobilization techniques, container design and life, package weight, toxic and corrosive materials amounts and composition, free liquid content, criticality, thermal power, and concentration and amount of radioactivity. In compiling the Waste Acceptance Criteria, DOE considered current regulations from the EPA, USNRC, and transportation requirements. The Waste Acceptance Criteria

[5]The Resource Conservation and Recovery Act establishes a system for tracking and regulating hazardous wastes from the time of their generation through disposal. In 40 CFR 264, EPA promulgated the "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (see the Glossary). EPA delegated authority over mixed waste in New Mexico to NMED (see Appendix D).

[6]With an exemption from Land Disposal Restriction regulations (40 CFR 268), Congress determined that WIPP waste does not need treatment prior to disposal. As a result, the NMED imposed groundwater and air monitoring requirements to ensure that any detectable release of hazardous materials remains below specified limits that have been established to protect human health and the environment.

have been revised several times since 1980 to reflect programmatic changes approved by NMED, EPA, and USNRC. All revisions to the Waste Acceptance Criteria require review of possible environmental impacts.

SIDEBAR 3.1 THE WESTERN GOVERNORS ASSOCIATION

In addition to the entities that have statutory authority over transportation, the Western Governors Association (WGA) has agreements with the U.S. Department of Energy (DOE) about certain controls that they will jointly impose on transportation within their individual member states; the purpose of these agreements is to ensure that no state will permit activities that may be harmful to the public in that or another state. The goal of the WGA is to help expedite cleanup of radioactive waste from member states and, specifically for the Waste Isolation Pilot Plant (WIPP), to ensure safe and uneventful transportation of waste to its final disposal location.

The WGA addresses the following elements of the transportation program:

- accident prevention:

  -high-quality drivers and carrier compliance,
  -independent inspections,
  -bad weather and road conditions,
  -safe parking during abnormal conditions,
  -advance notice of shipments, and
  -access to information on shipment status;

- emergency preparedness:

  -mutual aid agreements,
  -emergency response plans and procedures,
  -training and retraining, and
  -emergency response equipment;

- medical preparedness;
- route designation;
- public involvement and information; and
- program evaluation.

The WGA has a Board of Directors consisting of the Governors of Alaska, American Samoa, Arizona, California, Colorado, Guam, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Northern Mariana Islands, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. In addition, it has established a Technical Advisory Group consisting of representatives from Arizona, California, Colorado, Nebraska, Nevada, New Mexico, Oregon, Washington, and Wyoming.

A Memorandum of Agreement entitled *Regional Protocol for the Safe Transport of Transuranic Waste to the Waste Isolation Pilot Plant* was originally signed in 1996 by the Western States and DOE, and it was reviewed and reaffirmed in 2003 (WGA, 2003). The WGA Transportation Safety Program issued the *WIPP Transportation Safety Program Implementation Guide* in August 2002 (WGA, 2002). This guide contains detailed information about transportation and emergency procedures to be followed during shipments of TRU waste to WIPP. The DOE-Carlsbad Area Office, working with the WGA and 10 “corridor states,” has agreed to conduct the TRU shipping campaign employing standards and procedures negotiated through the cooperative program (as set forth by the Transportation Safety Program and its guide), many of which are more stringent than federal regulatory requirements.

The 1996 Memorandum of Agreement contains the following WGA expectations that have a direct bearing on TRU waste characterization activities:

1. The Western Governors expect DOE to fulfill the commitment made by the Secretary of Energy in the 1996 Memorandum of Agreement and to follow the WGA procedures contained in the *WIPP Transportation Safety Program Implementation Guide,* as amended, for the transport of all transuranic waste through the Western States, whether to WIPP or to a site for interim storage, characterization and/or repackaging. The governors further encourage the Secretary to provide the DOE-Carlsbad Area Office with the resources to implement their charter as specified in the National TRU Waste Program to manage all transuranic waste handling and transportation activities.
2. To ensure that the preceding objectives are met, the Western Governors support the following policy positions:

- DOE must continue to comply with both the letter and the spirit of all applicable requirements specified in the WIPP Land Withdrawal Act.
- DOE must work cooperatively with the U.S. Environmental Protection Agency (EPA) in its ongoing re-certification of WIPP's compliance with the applicable disposal standards and criteria in 40 CFR Parts 191 and 194. DOE's strict compliance with EPA standards is imperative.
- DOE must take immediate action to secure and/or allocate additional funding to TRU waste characterization and certification activities at DOE sites in order to facilitate the timely, efficient cleanup of the U.S. nuclear weapons complex. These funds should not be taken from the WIPP program, thereby limiting its ability to increase throughput, meet safety and environmental requirements, and continue the safe and uneventful transport of these wastes.

The impact of changes to the waste characterization program on WGA's agreements with DOE is discussed in Chapter 6, Finding and Recommendation 5.

3.3 HISTORY OF MODIFICATIONS TO WIPP'S REGULATORY DOCUMENTS

Since the beginning of WIPP operations (1999) there have been a number of modifications of the EPA Certification, the HWFP, and the USNRC Certificate of Compliance for shipping containers. With time and experience, changes to permits and certifications have become more focused, in particular those for the HWFP (e.g., data management and electronic quality assurance). According to DOE, these regulatory changes have been beneficial to the National TRU Waste Management Program (Kehrman, 2002).

3.3.1 Programmatic changes relevant to EPA

The EPA process for modifying the WIPP certification is described in Sections 194.4, 194.65, and 194.66 of WIPP compliance criteria (40 CFR 194). In brief, the process is as follows. There is only one level of “modification” to the certification. Any modification is done through rulemaking, with required *Federal Register* notices, a comment period, and responses to comments. Revocation of the WIPP Certificate of Compliance would also require rulemaking. EPA can suspend the certification at its discretion to address immediate threats to public health or the environment whenever the disposal activities or disposal system change such that significant information contained in the most recent compliance application were no longer to remain true (e.g., if releases from the disposal system were discovered that might exceed release limits).

EPA may approve WIPP program changes outside the modification process. In fact, DOE is required to report to EPA any planned program changes, which are evaluated to determine whether they are significant enough to challenge the basis for the certification decision. Thus far, no changes have risen to this level. EPA has approved a number of program changes through written notifications to DOE. In the case of such written approvals, EPA has the discretion (but is not required) to publish a *Federal Register* notice and/or solicit public comment, although so far it has not done so.

DOE has proposed a number of programmatic changes to EPA, some of which have been approved (see below). In December 2002, DOE submitted a request to EPA to dispose of RH-TRU waste in WIPP. To date (December 2003), EPA has not issued its decision. On its own initiative, EPA has proposed the following changes to EPA's compliance criteria (40 CFR 194):

- *Change in the waste characterization program approval process.* This would add flexibility and focus EPA's oversight efforts where EPA feels they would be most effective. The change would enable EPA to issue a single approval of each site's program, followed by ongoing EPA inspections and reporting of important changes by DOE.
- *Change in the focus of EPA's public comment process.* This change would highlight EPA's proposed decisions on site-specific waste characterization programs instead of focusing on plans and procedures prepared by DOE.
- *Change in the process to address minor modifications of the EPA Compliance Criteria.* This would streamline the process for editorial or other minor changes to 40 CFR 194.
- *Change in the document submission process.* This would allow non-paper submission (such as a compact disc) of compliance applications and reference materials to facilitate review by EPA and the public.
- *Replace the term “process knowledge” with “Acceptable Knowledge.”* This would allow EPA and DOE to use the same terminology consistently.

The public comment period for this rulemaking is now concluded. EPA is preparing the final rule on alternative provisions to 40 CFR 194, to be published in the spring of 2004. According to EPA, the purpose of these provisions is to add flexibility to, and clarify minor portions of, the rule while continuing to protect the public health and the environment. The rationale for modifications proposed by EPA is that the WIPP Compliance Criteria and Conditions of Certification (including requirements for inspection and approval of waste generator sites) were initially based on the best knowledge available at the time regulations were issued and DOE's Compliance Certification Application was submitted (1996).

Since the initial certification (1998) and beginning of operation (1999), EPA has gathered extensive experience implementing the requirements and has conducted many independent technical reviews and inspections of WIPP and DOE's TRU waste facilities around the United States to verify compliance with WIPP disposal regulations. Based on this experience, EPA determined that the processes dealing with inspections for the approval of TRU waste facilities in its Certification should be updated. EPA plans to apply this experience to improve its regulation of WIPP (EPA, 2002). EPA adds that these proposed changes will have no effect on the technical approach used during its independent inspections to evaluate a site's waste characterization capabilities. They also will not lessen the requirements that the site must meet to demonstrate compliance with EPA Certification

3.3.1.1 Approved programmatic changes

The following are notable programmatic changes submitted by DOE and approved by EPA. None of these changes required a modification of the EPA Certification. The first is a waste characterization-related change, the remaining are related to the WIPP facility:

- radioassay requirements used as an indicator of program performance were reduced from twice per year to once per year;
- magnesium oxide “mini-sacks” emplaced around the waste were eliminated; and
- the repository horizon was changed to a different depth.

The change in radioassay requirements reduces impacts on laboratories given that the national standards provide adequate quality control. The magnesium oxide change reduces worker doses (10 person-rem reduction over the entire facility capacity) and the amount of magnesium oxide by 15 percent. The change in repository horizon was approved to improve repository ground conditions, reduce risks during mining and waste handling underground, and reduce required maintenance.

3.3.2 Programmatic changes relevant to NMED

The New Mexico Hazardous Waste Act authorizes the NMED to establish procedures to modify a permit. EPA has identified three classes of permit modifications of hazardous waste (RCRA) permits:

- Class 1 permit modifications are minor changes that do not require NMED approval, such as typographical errors. No opportunity for public comment is allowed on Class 1 modifications, and the public is not informed until after they are implemented by the permittees.
- Class 2 permit modifications are minor changes that require public notice and a 60-day public comment period before a final determination by NMED to approve the modification with or without changes, deny it, or reclassify it as a Class 3 permit modification.
- Class 3 permit modifications are modifications that substantially alter the facility or its operations. The procedure is similar to that for the original permit. Class 3 modification requires public notice, public comment for at least 60 days, development of a draft permit, and the opportunity for full public hearings. The processing time for this type of permit modification takes anywhere from several months to a year from issuance of the draft permit until a final determination by NMED.

The history of Class 2 and 3 permit modifications since the release of the HWFP (1999), their outcome, and the time elapsed between submission and action dates on behalf of NMED are discussed in a recent report by the New Mexico Environmental Evaluation Group (EEG, 2003b). Out of 40 items contained in 18 Class 2 or 3 permit modification requests, 24 have been approved (as is or with modifications), 7 have been withdrawn, 5 have been rejected, and 4[7] are still in process. Among the requests in process, is the request to allow RH-TRU waste in WIPP. Major approved changes to the HWFP are described below.

3.3.2.1 Approved changes to the HWFP

The most significant permit modifications that have been proposed by DOE and accepted by NMED are the following:

- allow compositing of headspace gas samples prior to analysis for waste at the Idaho National Engineering and Environmental Laboratory (enabled this site to achieve its target date of 2002 for the first 3,100 cubic meters of TRU waste shipped to WIPP);
- allow statistical headspace gas sampling and analysis for thermally treated waste (Rocky Flats Environmental Technology Site reports saving more than $30 million in headspace gas characterization cost for 17,300 drums of residues in pipe overpacks);
- determine the mis-certification rate by performing visual examination as a quality control check on radiography on a summary category group rather than individual waste streams (Rocky Flats Environmental Technology Site reports saving more than $19 million by not having to determine and implement a mis-certification rate for every waste stream); and
- lengthen the compliance schedule for groundwater data reports (60 additional days are allowed to obtain and validate the analytical data).

3.3.3 Programmatic changes relevant to the USNRC

The USNRC public meeting process allows applicants (e.g., DOE) to meet with USNRC staff to discuss technical, licensing, and schedule issues prior to submitting an application. Based on the results of any public pre-application meeting, the applicant may decide to modify the application or not submit it. Records of the certification process for the TRUPACT-II shipping container indicate the DOE and its contractors met with the USNRC 14 times prior to formally submitting this certification modification (USNRC, 1989).

Thus far, the USNRC has not rejected any formal TRUPACT-II certificate modification request. Meetings between DOE and the USNRC concerning shipping containers certificate modifications are open to the public for observation and comment, but there is no regulatory mechanism for public participation in the decision.[8] To date (December 2003), the USNRC has approved 16 revisions of the TRUPACT-II Certificate of Compliance as well as 1 revision of the Half-PACT Certificate of Compliance. The following are the most significant modifications.

3.3.3.1 Approved changes to the USNRC Certification

The main changes to the USNRC Certificate of Compliance for TRUPACT-II shipping containers approved thus far are the following:

- additional contents such as various pipe overpacks;

[7]An additional Class 2 permit modification request has been submitted since the EEG report was published: DOE is proposing to eliminate headspace gas sampling for the Los Alamos National Laboratory sealed source waste (see Section 2.3.5.2). NMED has not yet published its decision.

[8]Such is not the case in USNRC rulemaking decisions (e.g., changes in 10 CFR 71).

- flammability assessment methodology;
- drum age criteria and prediction factors;
- headspace gas sampling to qualify test category waste;
- mixing shipping categories based on chemical compatibility;
- radiolytic hydrogen yields (G values[9]) vary with dose and type of radiation and take into account matrix depletion; and
- shorter shipping periods (from 60 to 5 days) to WIPP for a particular waste stream from Los Alamos National Laboratory.

The 5 percent volumetric limit on flammable gas (in particular hydrogen) generation in the innermost confinement volume of shipping containers has been one of the greatest challenges for DOE. In the case of waste with high potential for flammable gas generation (see Section 2.3.1), transportation limits on amounts of radioactivity in the TRUPACT-II container severely restrict the amount of allowed waste per shipment. WIPP has been successful in developing applications to the USNRC for certificate revisions to increase payload (e.g., matrix depletion allowance) and is working toward further revisions (e.g., use of hydrogen "getters").

A DOE initiative, recently discussed with the USNRC, is that of using a "no-consequence" container (called ARROW-PAK) as a secondary waste container that could mitigate the effect of a deflagration caused by hydrogen buildup. According to DOE, this may be the object of a proposed revision of the Certificate of Compliance but no such request has yet been submitted to the USNRC. An exemption from parts of 10 CFR 71 may be necessary to allow use of the ARROW-PAK because a flammable mixture could be present in shipping containers.

3.4 DISCUSSION: REGULATORY CHALLENGES AND MILESTONES FOR TRU WASTE CHARACTERIZATION

In addition to the waste characterization challenges mentioned in Chapter 1 (see Section 1.6), characterizing TRU waste presents additional challenges due to the following:

- *Uniqueness of the WIPP facility.* WIPP is a first-of-a-kind facility and therefore its regulators have to issue non-routine permits[10] (see Sidebar 3.2).
- *Compliance with several regulatory documents.* WIPP must be in compliance with the three main regulatory documents: the NMED HWFP, the EPA Certificate of Compliance for the WIPP facility, and the USNRC Certificate of Compliance for shipping containers (see Section 3.2.4). DOE must also comply with regulations promulgated by several other agencies that do not have direct regulatory oversight of WIPP activities (see Table C.1 in Appendix C).
- *Variability in the definition of waste stream.* Waste is categorized into waste streams based on how it is produced, its waste categories, and waste matrix codes, depending on the agencies. In the EPA Certificate of Compliance certification application, DOE identified 569 waste streams based on historical knowledge, while EPA sorted WIPP waste inventory by volume in 10 waste categories, and NMED identified 11 Waste Matrix Code Groups (see definition of waste stream in the Glossary).

[9]For a definition of G value, see the Glossary.

[10]The term "non-routine permit" is used here to describe any regulatory document—such as permit, license, or certification—that is issued on a one-of-a-kind operation or facility that does not have a specific license guide, regulatory guide, or regulation section. A non-routine permit is based on the basic principles of the regulations and normal health and safety practices.

SIDEBAR 3.2 NON-ROUTINE PERMITS

Non-routine permits (sometimes called "negotiated" permits) differ from routine permits issued for activities that are covered by a specific section of the regulations or by general regulations. Non-routine permits usually address activities that are not specifically addressed in the regulations; are new processes employing unproven techniques or technologies; or reflect a new application of an existing process. U.S. Nuclear Regulatory Commission non-routine licenses were granted to the uranium hexafluoride production facility Honeywell International in Illinois; to gaseous diffusion enrichment facilities at Paducah, Kentucky, and Piketon, Ohio; and to the low-level waste disposal site of Envirocare, Utah.

In non-routine permit cases, the regulator must apply, within a broader regulatory framework, professional judgment regarding necessary safety items, level of characterization, safety monitoring, environmental monitoring, record keeping, required safety equipment, limitations of the quantity of radioactive material or hazardous wastes to allow on-site, operating procedures, and level of supervision or safety oversight required. A particularly useful tool for the regulator is a limited (short) time frame for the permit to expire. The extent of regulatory constraints imposed may be based on the nature of the applicant and history of the applicant with the regulator (or other regulators); the nature of the activity; the potential hazard presented to workers, the public, and the environment; and knowledge of the proposal demonstrated by the applicant, as well as the quality of the permit application. Important considerations are what items have the greatest potential to increase worker or public risk or to create major accidents or incidents.

This conservative approach is taken by the regulator because it is easier to agree with the permittee on restrictive and conservative requirements up front than it is to attempt to impose them after operations have begun. It is also intended to enhance protection of workers, the public, and the environment during the startup phase of new operations and reduces the likelihood of an accident. This is true even in the regulated radiation arena where such actions by the regulator have been undertaken rather routinely.[a] Being conservative is helpful because in many cases it may not be clear to the applicant or regulator exactly what approach would be best in the final analysis. With this process, the applicant may continue operating safely as it gathers the information and experience necessary to modify safety requirements so that they ensure protection and increase efficiency of operations. Generally, the permittee has the right to request an amendment to the permit, changing the scope of activities, operations, or kinds and amounts of radioactive material or hazardous waste to be processed. Changes in the scope of authorized activities may require changes in the protection program. In any event, the permittee is required to comply with the conditions of the specific permit and the regulations.

[a]A major difference between the two compliance requirements is the comprehensive coverage provided by the radioactive material license, which addresses all aspects of protection (public, worker, and environment) versus the hazardous waste permit, which addresses environmental protection.

- *Meeting the cleanup agreements with the sites.* DOE must meet sites' cleanup milestones set forth by DOE's compliance agreements with EPA and generator states' regulators, such as Federal Facility Compliance Agreements and Tri-Party Agreements. For instance, DOE has made a commitment to the State of Colorado to close the Rocky Flats Environmental Technology Site by December

15, 2006. The Idaho Settlement Agreement with DOE stipulated that the Idaho National Engineering and Environmental Laboratory must ship at least 3,100 cubic meters of TRU waste out of the State of Idaho by December 31, 2002 (this was called the "3100 Project").

- *Compliance with the ALARA (as low as reasonably achievable) principle.* Under federal law, DOE has the responsibility and authority to self-regulate and has issued 10 CFR 835 to protect worker health and safety in every DOE facility. Various requirements include the application of the ALARA principle. This principle states that DOE must keep workers' radiation exposures as far below the regulatory dose limit[11] as reasonably achievable. Moreover, DOE must ensure that all waste is managed in a manner that is protective of worker and public health and safety, and of the environment, as specified in DOE's Order 435.1.
- *Compliance with DOE internal drivers.* Timeliness and cost of cleanup are two internal DOE drivers. DOE managers are under pressure to complete site cleanup and send waste to WIPP "faster, better, cheaper."
- *Compliance with WGA agreements.* These agreements are essential to transportation of TRU waste from the Western States to WIPP (see Sidebar 3.1).

The challenges of regulating a unique facility, such as WIPP, are discussed below.

3.4.1 WIPP as a First-of-a-Kind Facility

One of the major regulatory challenges for WIPP is its unique nature. WIPP is the first U.S. geologic repository for transuranic and mixed radioactive waste, and as such, regulating the geologic disposal of TRU waste in it is a unique endeavor. In particular, demonstrating compliance with radioactive waste disposal regulations over 10,000 years (the regulatory compliance period) is a difficult task for both DOE and EPA. In the absence of an established licensing or permitting path, the waste characterization program was negotiated between DOE and EPA over a period of two decades. Many of the most conservative requirements were originally proposed by DOE on the basis of existing requirements for the transportation of radioactive waste. For instance, DOE introduced rigorous measures in its waste characterization program, including 100 percent sampling, redundant testing, and extensive confirmation of existing data for the purpose of compensating for the absence of experience in handling this aged waste. Furthermore, explosives, combustible materials, corrosive materials, and chemically reactive materials—all prohibited items in the HWFP—are also prohibited by the U.S. Department of Transportation from being transported in the same shipping container as radioactive waste.

WIPP regulators (EPA and NMED) declared the facility in compliance with the relevant regulations when they issued the Certificate of Compliance and the Hazardous Waste Facility Permit in 1998 and 1999, respectively. Because of the unique nature of WIPP, its Certificate of Compliance and the HWFP for WIPP are considered non-routine regulatory documents. As shown in Sidebar 3.2, the general pattern of licensing of a facility not specifically addressed by existing regulations is to begin in a conservative fashion (i.e., the regulator applies rigorous licensing requirements to such a facility until the permittee demonstrates what safety or process items are most representative of the operation being licensed and provide adequate protection). Equally important (or perhaps even more important) are what items have the most potential to create accidents or incidents. By starting with a conservative approach, the applicant can acquire operational experience while ensuring worker and public protection. At the same

[11]The limits for radiation doses to workers were first established in 10 CFR 835.

time, the information necessary to determine those items that ensure adequate protection of health and safety can be determined. Generally, the permittee has the right to request an amendment to the permit that may change the scope of activities or kinds and amounts of radioactive material or hazardous waste to be processed, provided the applicant can support the request with adequate justification for the amendment. This has been the case with NMED's Hazardous Waste Facility Permit and with the EPA and USNRC Certificates of Compliance.

3.5 DISCUSSION: EXPERIENCE WITH THE PERMIT MODIFICATION PROCESS

DOE has successfully submitted modification requests for its HWFP, EPA, and USNRC permits to streamline characterization activities and make the process more cost- and time-effective. As shown above, the permit modification process differs depending on the regulatory agency (EPA, USNRC, or NMED). With the EPA and USNRC the process involves frequent interactions between the regulator and the applicant before a certification modification request is submitted. This approach shortens the time and increases the efficiency of the process. It also decreases the probability of rejection once the modification request has been submitted.

The HWFP modification process is different because it does not stipulate interaction between DOE and NMED before the permit modification request is formally submitted. As required by regulations [40 CFR 270.42 (b)(6)(ii)], all Class 2 permit modification requests submitted thus far have been either approved, denied, or reclassified as Class 3 modifications within 120 days after receipt by NMED. Only one Class 3 permit modification request has been approved to date (for headspace drum age criteria; see Section 4.1), for which the entire process took anywhere from 613 days (DOE's estimate) to 810 days (NMED's estimate, based on receipt of the Class 1 permit modification on November 18, 2000, to issuance of the revised permit on February 6, 2003).

The long delay in receiving approval for this request is due to the following: 1) misclassification of the permit modification request by DOE; 2) the public participation process mandated by regulation; and 3) delays in processing the application by NMED. DOE initially submitted the request as a Class 1 permit modification, which was verbally rejected by NMED within two days of receipt as an inappropriate classification. DOE submitted the same request as a Class 2 permit modification, which—after public comment—was rejected by NMED. DOE revised the permit modification request and submitted it again as a Class 2 which, after public comment, was determined by NMED to require a draft permit and was thus reclassified as a Class 3 request. NMED took considerable time to develop a draft permit based on public comment and its own technical evaluation. After issuance of a draft permit for public comment, NMED held a public hearing on the permit modification request and, after allowing for full public participation, issued a ruling and revised the draft permit based on all public comment. The policy and societal impacts of changes to the characterization program are discussed in Sections 5.5 and 5.6.

4

Transuranic Waste Characterization Program

This chapter describes the current (2003) contact-handled transuranic (CH-TRU) waste characterization program as approved by the New Mexico Environment Department (NMED) and the U.S. Environmental Protection Agency (EPA), and implemented at the five U.S. Department of Energy (DOE) waste generator sites shipping waste to the Waste Isolation Pilot Plant (WIPP). Emphasis is given to the concept of "Acceptable Knowledge" (AK), a central feature of the characterization program. Lessons from experience and future opportunities to take advantage of, in the context of waste characterization, are presented at the end of this chapter (Section 4.6).

4.1 OVERVIEW OF THE CURRENT WASTE CHARACTERIZATION PROGRAM

The committee describes the CH-TRU waste characterization program as a suite of characterization activities that are performed at generator sites before shipping waste to WIPP (see Figure 4.1). These activities address requirements set forth by Congress (through the Land Withdrawal Act), EPA, NMED, and the U.S. Nuclear Regulatory Commission (USNRC). Regardless of the time of generation (i.e., existing or to-be-generated), TRU waste is divided into three categories for characterization purposes: homogeneous waste, debris waste, and debris waste that needs repackaging. All waste being characterized is solid waste because liquids are prohibited in WIPP. Homogeneous solids are solid residues such as inorganic sludge, salt wastes, or pyrochemical salt wastes that are expected to contain TRU radionuclides, toxic metals, and solvents. Homogeneous solids range from de-watered sludge with the consistency of paste to solid cement.

Debris waste, as its name suggests, consists of heterogeneous solids. Debris waste includes such items as protective clothing, gloves, rags, laboratory instruments, and parts of equipment such as gloveboxes. Some debris waste inventory has to be repackaged in a form suitable for shipment (see below). Characterization activities vary depending on the category of solid waste. Wastes are characterized following the same set of activities independent of their time of generation (i.e., existing waste and to-be-generated waste are characterized in the same fashion if they belong to the same waste category). According to DOE, there are approximately 750,000 drums of CH-TRU waste remaining to be characterized (DOE-CABE, 2003).

Waste characterization activities for CH-TRU waste, including recent changes, are described in the following sections based on information provided by DOE (DOE-CBFO, 2002), the Center for Acquisition and Business Excellence (DOE-CABE, 2003), and the New Mexico Environmental Evaluation Group (EEG, 2003b). A detailed description of the characterization activities is presented in the Waste Acceptance Criteria (DOE-WAC, 2003) and in Attachment B of the HWFP (HWFP, 2003).

4.1.1 Acceptable Knowledge

AK is a term that encompasses historical process knowledge and information from previous testing, sampling, and analyses of waste. DOE coined this term based on

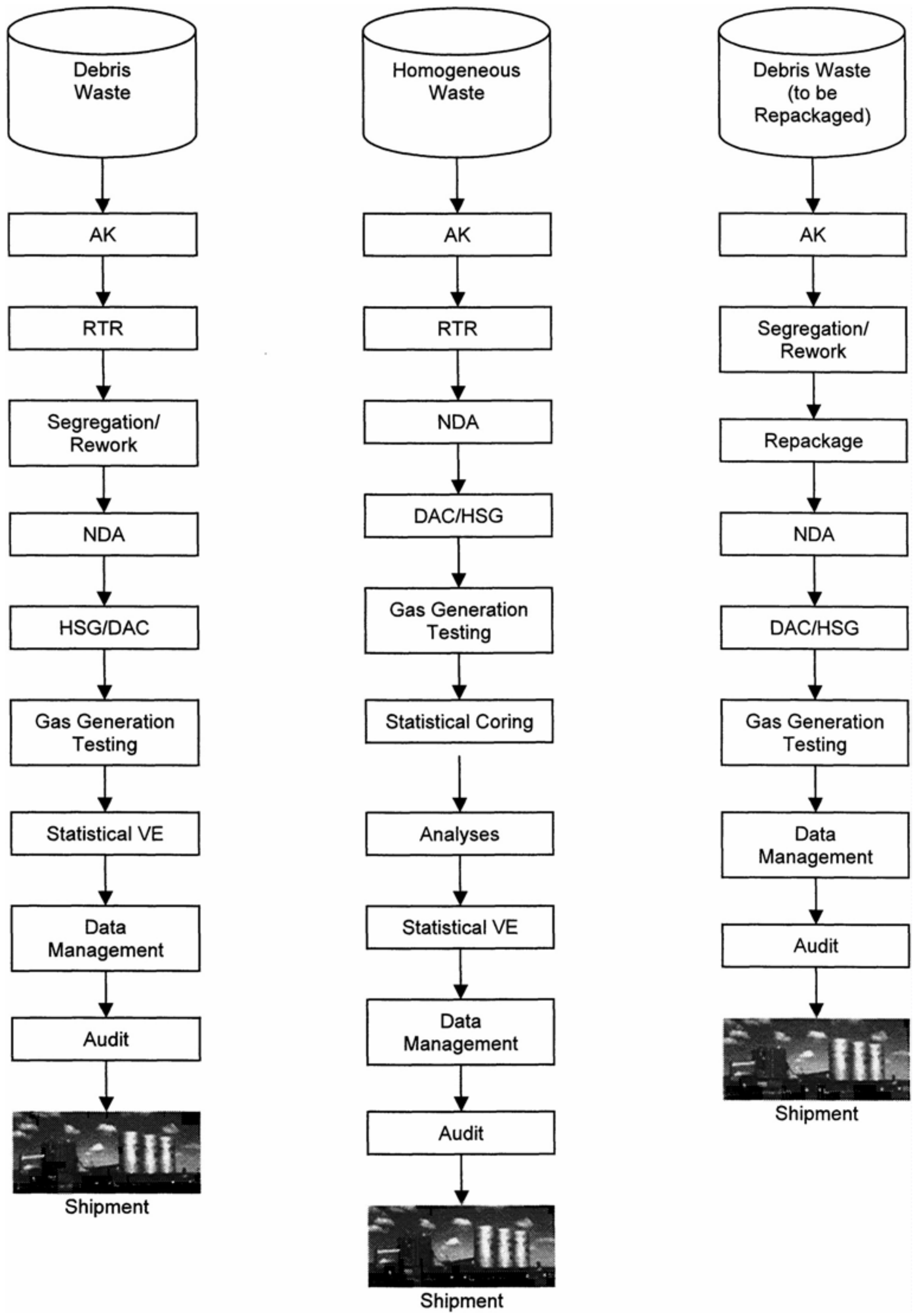

FIGURE 4.1 Summary of typical characterization activities in the current contact-handled transuranic waste characterization program. Characterization activities may vary among generator sites. NOTE: AK=Acceptable Knowledge; DAC=drum age criterion; HSG=headspace gas sampling and analysis; NDA=Non-destructive assay; RTR=real-time radiography; and VE=visual examination.

EPA's similar concept of process knowledge; EPA has recently adopted the term "Acceptable Knowledge" when referring to WIPP processes to be consistent with DOE terminology (see further discussion in Section 4.4).

4.1.2 Real-time radiography and visual examination

Real-time radiography is a non-destructive examination technique usually involving X-ray imaging technology. Visual examination is an invasive process that involves opening a TRU waste container to inspect its contents. Radiography, visual examination, or a combination of both are used on every waste container to verify its physical form, confirm the absence or presence of prohibited items, and evaluate the masses of various fractions of materials important to the performance of WIPP, such as ferrous metals, non-ferrous metals, cellulose, or plastics and rubber.

With recent changes to the HWFP, generator sites have the choice to characterize to-be-generated waste with visual examination or radiography, the latter to be verified through visual examination on a statistical fraction of containers as a quality control check. Sites may elect to use visual examination before or radiography after packaging, either separately or together, as long as 100 percent of the containers undergo confirmation of AK.

The visual examination process can be performed in two ways: 1) two certified operators perform the visual examination process; or 2) a certified operator examines a videotape of the waste removal and sorting process. In addition, approximately 1.2 percent of the containers ultimately disposed of at WIPP (or approximately 9,000 drums) must undergo a quality control check of radiography results by visual examination. Containers found to have prohibited items are also visually examined and reworked (i.e., the container is opened in a glovebox and prohibited items are removed, see below).

4.1.3 Non-destructive assay

Non-destructive assay is a general term for a number of non-invasive techniques, such as gamma spectroscopy and passive-active neutron measurement. These techniques provide information about the radionuclide content of waste and whether waste is TRU without destroying the waste or waste form.

4.1.4 Drum age criterion and headspace gas sampling and analysis

Both the NMED and the USNRC have requirements for headspace gas (HSG), which is the gas developed in the void volume of waste containers (e.g., 55-gallon drums). The NMED requirements are to support hazardous waste determination. The USNRC requirements are to determine that only non-flammable gases are present. Both requirements are satisfied by a single procedure, called headspace gas sampling and analysis. Headspace gas sampling and analysis is used to:

- identify and quantify volatile organic compounds (VOCs[1]),
- confirm AK for hazardous waste identification, and
- identify and quantify flammable gases (hydrogen and methane) for transportation purposes.

[1]There are 29 VOC species that are required to be characterized quantitatively in the WIPP HWFP permit. The amounts of VOCs in the waste shipped to WIPP to date have been small (about 5 ounces summed over the 40,000 drums emplaced in Panel 1). The predominant species found (more than 90 percent by mass) are acetone, 1,1,1-trichloroethane, toluene, methylene chloride, and carbon tetrachloride.

Headspace gas sampling and analysis uses gas chromatography/mass spectrometry, flame-ionization gas chromatography, or Fourier-transformation infrared spectroscopy to analyze headspace gases. This characterization activity also involves aging the drum for a prescribed number of days (up to 242) to allow equilibration of gases in the headspace prior to sampling and analysis. The required waiting time prior to headspace gas sampling is referred to as the drum age criterion.

All waste is verified by 100 percent headspace gas sampling, except homogeneous solids without VOC-related hazardous waste codes, or thermally treated wastes (see Section 4.2). A small portion of the containers (approximately 1.8 percent) requires new vents prior to shipping,[2] and over two-thirds of the containers (68.7 percent) require documentation to show compliance with the drum age criterion.

4.1.5 Gas generation testing

Gas generation testing at elevated temperatures is performed for transportation requirement purposes although it is not part of the WIPP Waste Acceptance Criteria or the waste analysis plan in the Hazardous Waste Facility Permit (HWFP). This test is used to measure gas generation rates for wastes whose historical information suggests that flammable gases might exceed the limits for transportation.

In the test, waste drums suspected to contain higher-than-normal concentrations of hydrogen-bearing or organic compounds are heated to an elevated temperature to measure the amount of gas generated. This method accounts for both radiolytic hydrogen or methane generation (the predominant source of flammable gases) and any VOCs (if present) that might be driven out of the waste into the headspace gas by elevated temperatures during shipping in the summer months. If the test shows that the container would not generate enough flammable gas during shipping to produce an explosive mixture in the transportation package, the container may be shipped. Approximately 9 percent of the remaining legacy waste population of containers, i.e., 41,000 drums (8,550 cubic meters), is expected to require elevated-temperature gas generation testing (DOE-CABE, 2003).

4.1.6 Homogeneous waste coring and analysis

Homogeneous waste forms can be sampled in a way that is representative of the bulk of the waste. These wastes undergo statistical coring and analysis, which determine the chemical composition and concentrations of hazardous waste constituents and the toxicity characteristics of waste in containers (see Section 4.2). “Coring” is a process wherein a container of solids is opened, and a hollow drill bit is used to obtain a core that reaches from the top of the waste to a depth near the bottom of the container. The core is taken from the bit and “sampled” by removing either one or three thin sections from along its length. These sections become the sample.

For retrievably stored wastes, the HWFP states that homogeneous sampling and analysis is used to determine the toxicity “characteristic” in the waste; that is, the hazardous compounds that are considered toxic only if present above the threshold concentrations listed in 40 CFR 261.24, or if the “listed” wastes under Subpart D of 40 CFR 261 are present. The HWFP requires analysis of homogeneous samples for total

[2]Most but not all retrievably stored drums have filter vents installed at the time of generation. When a drum is exhumed or retrieved and does not have a vent, usually the site safety procedures require immediate venting (installation of a filter). Also, there are some waste streams that have shown filter degradation over times, and those streams have a routine filter replacement schedule. Finally, at certain sites, the headspace gas sample is collected through the filter; in this case too, the filter must be replaced.

VOCs, semivolatile organic compounds (SVOCs), and analysis for metals. Tables in the HWFP list over 30 chemicals for the VOC analysis, 11 for the SVOC analysis, and 14 metals that are the primary targets, but other hazardous constituents may be added to the list for a waste stream if they are found in more than 25 percent of the samples from that waste stream (EEG, 2003b).

4.1.7 Segregation or rework

Segregation or rework are the activities required when a container is found to be out of compliance with the Waste Acceptance Criteria (e.g., if real-time radiography or visual examination finds a prohibited item in a container, that container is segregated from the others, the prohibited item is removed, and the waste is repackaged).

4.1.8 Repackaging

Repackaging involves removing all contents from the original waste container, sorting, size-reducing, compacting,[3] and putting them into new containers. During repackaging, waste that is not suitable for shipment and does not meet the hydrogen generation limits for transportation is removed from the containers.

4.1.9 Data management

Data management includes the data-gathering operations and quality assurance activities that the waste generator and the Department of Energy (DOE) perform to assemble, record, and certify the information on each container and to assist in managing each transportation payload container. DOE uses a quality assurance process based on that used by nuclear power plants (NQA-1) on all TRU waste characterization and certification activities. The quality assurance process that is now described in the HWFP requires, among other activities, the review, validation, and verification of all analytical data; reconciliation of analytical results with data quality objectives (DQOs); satisfying data reporting requirements; and identification, documentation, and reporting of all non-conformances.

Data review determines whether raw data have been collected properly and ensures that raw data are properly "reduced" to an acceptable format. Data validation confirms that the data reported satisfy the requirements of the waste analysis plan and are accompanied by the approval of an authorizing official. Data verification authenticates that data as presented represent the sampling and analysis activities as performed and have been subjected to the appropriate levels of data review. Other quality assurance activities, such as statistical calculations for random sampling, confidence levels from analyses, evidence of independent technical review, supervisor review, quality assurance review, chain-of-custody and sample preservation are also described in Attachment B5 of the HWFP (HWFP, 2003).

As part of data management activities, sites transmit required characterization, certification, and shipping data to WIPP prior to shipping using the WIPP Waste Information System. This system consists of an electronic database equipped with edit-limit checks to ensure that the data representing the waste payload containers comply with the Waste Acceptance Criteria. Only DOE, EPA, NMED, the New Mexico Environmental Evaluation Group, and corridor state authorities have access to information in the database.

[3]Size reducing and compacting are performed only at certain sites, such as the future Advanced Mixed Waste Treatment Facility at the Idaho National Engineering and Environmental Laboratory.

The HWFP data management process is comprised of seven layers of review; some of the reviews are performed at generator sites and some at the DOE-Carlsbad Field Office. There are also quality assurance activities for transportation purposes, as described in Appendix D. According to DOE, it takes about two months for a waste container to go through the entire data management process (Powell, 2003).[4]

4.1.10 Audits

Audits are the operations conducted by DOE's auditing branch at generator sites to ensure that waste characterization sites conduct waste characterization activities in accordance with the HWFP Waste Analysis Plan, and that the information supplied by each site is managed properly. EPA, NMED, and the New Mexico Environmental Evaluation Group participate in these audits as observers and confirm that characterization requirements are addressed. They may request corrective actions to a site's characterization process if they believe it does not comply with the regulations.

4.2 STATISTICAL SAMPLING OR 100 PERCENT CONFIRMATION?

Some characterization activities are performed on all containers (e.g., non-destructive assays, headspace gas analyses, development of AK, and data management), whereas others apply to only a selected portion of the inventory (see Table 4.1 in Section 4.6). For example, homogeneous solids, soils, or gravel without VOC-related hazardous waste codes, or thermally treated waste may qualify for reduced headspace gas sampling. Debris waste does not undergo homogeneous sampling and analysis, and only a statistical fraction of homogeneous solids, soils, or gravel undergoes homogeneous sampling and analysis.

An example of statistical sampling is illustrated in the case of homogeneous waste solids. In this case, there are two levels of statistical significance. The first is the statistical significance of the samples collected from a container. The second is the statistical significance of samples collected across a waste stream.

The first part of statistical significance refers to sampling a container in a statistically representative way (more accurately called aliquoting); this can be done in several ways. One of these ways is coring and aliquoting from different layers (at least three are required in the HWFP). If the waste is in a cement matrix, coring involves drilling into the solid waste to collect aliquots. If the waste form allows it, sample gridding (i.e., pouring the powder into grids and then randomly aliquoting from the cells) can also be used to minimize entrainment of particulates.

The second part of statistical significance refers to how accurately a subset of samples from a waste stream represents the true mean of a parameter (e.g., the average lead metal concentration). In this case, the population variance must be known before deciding how many samples to collect. The greater the variance, the more samples are needed to achieve a given accuracy (as specified in the HWFP). For instance, the HWFP specifies how many waste containers from a determined waste stream must be sampled. From the results of the analysis of this first set of containers, the variance of the population is estimated, and a new calculation of the number of samples from that waste stream is made to achieve the required confidence level on the mean. If necessary, more containers are sampled until the required accuracy is achieved. Of course, if the first subset sampling results in the required accuracy, there is no need to continue sample collection. According to DOE-CABE, approximately 0.5

[4]DOE submitted a data management permit modification request to NMED on June 28, 2002 to implement automating data processes that would eliminate four of the seven levels of review. NMED has not issued a decision to date.

percent of the remaining containers, or 375 drums, will undergo statistical coring and analysis for hazardous constituents (see Table 4.1 in Section 4.6).

4.3 SITE-SPECIFIC CHARACTERIZATION ACTIVITIES

Characterization activities may vary somewhat from one generator site to another, depending on the type of waste to be characterized and on terms negotiated between the state in which the waste is generated and DOE. For example, the characterization activities at the future Advanced Mixed Waste Treatment Facility in Idaho and at the Savannah River Site are somewhat different. The Advanced Mixed Waste Treatment Facility has the capability to "supercompact" waste for volume reduction and more efficient operations.[5] Therefore, real-time radiography and/or visual examination are performed prior to compaction and/or final waste packaging. This facility also has the capability to size-reduce and repackage wastes from oversized waste boxes. EPA and NMED must approve the suite of characterization activities at each site before allowing waste to be shipped to WIPP. To date (December 2003), the Advanced Mixed Waste Treatment facility has not been certified.

The Savannah River Site has adopted a "fast-scan" approach to real-time radiography, which consists of performing a quick radiography scan of the waste containers during the weekend to identify prohibited items. Containers with prohibited items are set aside to be segregated or reworked at a later date, while those that do not appear to contain prohibited items follow the "quality-assured" characterization activities during the week. This approach is not part of the Waste Acceptance Criteria or the HWFP and was introduced by DOE to increase the efficiency of characterization activities (see also Section E.3).

A further example of site-specific changes to the characterization program is the headspace gas sampling and analysis process. At the Savannah River Site, the container is placed into a sampling chamber after it has met the required drum age criterion. A remotely controlled drill places a sampling port in the lid. First, a sample of headspace gas is drawn into a flame ionization detector, which quickly provides hydrogen and methane concentrations to determine if the headspace gas is below flammability limits for transportation purposes. Then, a second sample is drawn and injected into a gas chromatograph-mass spectrometer to analyze for 29 VOC species specified in the HWFP.

During the 3100 Project at the Idaho National Engineering and Environmental Laboratory, each container was sampled using a filter vent with a septum entry. A needle was inserted into each drum (manually) and a headspace gas sample was drawn into a canister to be combined with other canisters. These were shipped in drums (10 at a time-one canister per drum) to an analytical laboratory at some distance from the drum sampling area. First, ten aliquots (one from each canister) were taken. The aliquots were combined and a sample was injected into a flame ionization detector for flammability (hydrogen and methane). A second sample of the combined aliquots was injected into a gas chromatograph-mass spectrometer for VOC analysis.

The difference between the Savannah River Site and the Idaho National Engineering and Environmental Laboratory 3100 Project analytical methods is primarily in the lower limit of detection. With the Idaho National Engineering and Environmental Laboratory aliquots combined, the minimum detection limits are significantly increased.

[5]A recent report by DOE's Inspector General noted that there would be a 6 percent volume reduction for the 65,000 cubic meters of TRU waste from Idaho instead of the 35 percent initially estimated (DOE-IG, 2003).

However, only one gas chromatograph-mass spectrometer analysis per batch is needed, so some time is saved.

The Rocky Flats Environmental Technology Site obtained an exemption from the NMED requirement to perform headspace gas sampling and analyses on thermally treated waste (see also Sections 3.3.2.1 and E.4). DOE also submitted a request for HWFP modification to obtain an exemption from headspace gas sampling and analysis for the sealed sources stored at Los Alamos National Laboratory (see Section 2.3). NMED denied this permit modification request because DOE did not provide sufficient evidence that sealed sources do not contain hazardous waste (NMED, 2003b). The use of AK alone to determine the flammability of headspace gas is allowed by the USNRC, but DOE elected to measure flammable gas concentrations in each container.

According to DOE, the quality assurance requirements for the headspace gas analysis are more demanding than those for the flammability test for transportation purposes. First, headspace gas sampling and analysis requirements in the HWFP are linked with the SW-846 (EPA's Methods Manual), which introduces precision, accuracy, representativeness, completeness, and comparability criteria. Second, all of the headspace gas sampling and analysis requirements are subjected to scrutiny during the audit process. Third, other quality protocols come into play such as: 1) calibration standards at the ppm level, 2) instrument controls, and 3) follow-up analyses for “Tentatively Identified Compounds” at concentrations above the “Program Required Quantitation Level” for all 29 VOC species in the WIPP Part A Permit list. While the actual analyses and setup for flammable gases and VOCs require similar technical efforts and costs, meeting the HWFP requirements to determine the VOC concentrations requires a greater data management effort because of the number of analytes, associated calibrations, and quality assurance requirements (Nelson, 2003).

4.4 ACCEPTABLE KNOWLEDGE

The first step in the characterization process is the compilation of all relevant information available on the waste into an auditable record. This information is called AK. The AK record must include information that describes the amount and how the waste was generated and managed, as well as the physical, chemical, and radiological properties.

AK also includes information regarding the raw materials used in a process or operation, process description, products, and associated wastes. AK documentation includes the site history and mission, site-specific processes or operations, administrative building controls, and all previous and current activities that generate a specific waste (DOE-SAR, 2003).[6] According to the EPA's definition, AK may consist of a variety of information, such as the following (EPA, 1994):

- detailed waste analyses at the time of generation, if performed in accordance with an acceptable quality assurance program;
- studies of the waste generating process—in addition to information about the process flowsheet and its goals, these may include data from the generator's process, or from similar generation processes undertaken elsewhere, and from experiments involving surrogate waste processes or products;
- waste characterization data obtained from facilities that send wastes off-site for treatment, storage, or disposal;

[6]EPA is currently in the final stages of a rulemaking to change 40 CFR 194.8 to streamle its certification process of confirmation at generator sites. EPA has indicated that it will provide a more focused definition of AK in that rulemaking.

- the generator's records of analyses performed before the effective date of the Resource Conservation and Recovery Act (RCRA) regulations; or
- other historical data relevant to characterization of the waste (e.g., procurement records).

Acceptable Knowledge is developed on a waste stream basis. Once a generator site determines that a particular waste stream is suitable for disposal in WIPP, the generator begins collecting all relevant information available (i.e., the AK) for the waste stream. The collected AK is then reviewed and released by the generator site, following the regulators' procedures. This preliminary AK report contains the generator's assignment of a waste matrix code and a summary category group.[7] The latter specifies the physical form of the waste (homogeneous, soils or gravel, or debris) and hence the sampling and characterization regimen for the waste streams. The generator then submits to WIPP a Waste Stream Profile Form (brief summary of the AK report, with citations) and the AK Summary Report, which is approved by WIPP prior to shipment of any containers of waste from the waste stream in question.

The EPA recognized that under certain circumstances, the use of existing knowledge of a waste stream might be preferable to performing a detailed characterization. As acknowledged in joint USNRC/EPA guidance, mixed wastes constitute one of those circumstances because of the potential for personnel exposure inherent in radioactive waste characterization (USNRC/EPA, 1997). Although written for commercial mixed waste generators, the guidance states that it could apply to transuranic waste. Therefore, this guidance may also be useful for federal facilities that generate mixed waste, such as WIPP waste generator sites.

The concept and use of AK is central to the characterization program for TRU waste because it determines the sampling and characterization regimen for the waste. The AK process delineates the waste stream. If the required elements cannot be documented in the AK summary, the waste must be treated as "newly generated waste," according to DOE's terminology. AK forms the basis against which the results of other characterization methods are compared. This process is termed "confirmation of AK." The characterization methods used to confirm AK include non-destructive assay, headspace gas sampling and analysis, radiography and visual examination, and homogeneous solids sampling and analysis (DOE-CABE, 2003).

4.4.1 Uses of Acceptable Knowledge

The EPA allowed the use of AK to determine whether a waste stream was "characteristically" hazardous, to comply with the RCRA requirement to analyze a representative sample of the waste and determine its disposability. AK is used to address several characterization requirements set forth by different regulatory agencies. Uses of AK in the characterization program are the following:

- determine that waste is defense-related and TRU;
- assign waste to one of the 11 waste matrix code groups (see Chapter 3);
- assess the presence of toxic material;
- assess the presence of listed RCRA waste;
- determine the absence of non-radionuclide pyrophoric materials;
- determine the absence of liquids;
- determine the absence of incompatible wastes;

[7]For a definition of waste matrix code and summary category group, see the Glossary.

- determine the absence of containerized gas or explosives;
- determine the absence of reactive, corrosive, or ignitable waste characteristics;
- track the presence of polychlorinated biphenyls;[8]
- determine the absence of sealed containers greater than 4 liters; and
- determine the fissile material content.

If the waste was generated after the implementation of RCRA (1976), many of the above physical and chemical characteristics of waste are gathered from the hazardous waste codes assigned to the waste at the time of generation.

4.4.2 Qualification of Acceptable Knowledge

Based on EPA's requirements set forth in 40 CFR 194.22(b), historical information collected before an approved quality assurance program is in place must be qualified before it is used as AK. Title 40 CFR 194.22(b) lists four methods that may be used individually or in combination to qualify such data:

1. *Peer review.* In general, the use of peer review requires a structured and documented review process.
2. *Use of corroborating evidence.* This may include other data generated prior to approval of the quality assurance program or data on other waste streams that should be able to represent the one being considered.
3. *Confirmation by measurements.* These confirmatory tests must be performed in accordance with an approved quality-assurance program.
4. *Qualification of quality assurance program.* In practice, this means demonstrating that the quality assurance program in effect when the AK was generated was equivalent to a quality assurance program approved by WIPP.[9]

Currently, confirmation by measurements is the only method used to qualify existing information, as negotiated between DOE and its regulators. All information about existing waste collected before the establishment of a quality assurance program must currently be confirmed by some type of measurement to become AK. The types and frequency of confirmatory measurements vary depending on the particular waste and the site. For example, for debris waste, information is confirmed by using either real-time radiography or visual examination.

4.4.3 Accuracy of historical information

A key question is how to verify the accuracy of historical information about waste. The accuracy of AK is, according to the Waste Acceptance Criteria, to be verified on a waste stream basis, although AK is also used to define waste streams. How accuracy should be determined is not specified in the Waste Acceptance Criteria. However, DOE has established Data Quality Objectives for AK as required by the HWFP (2003; Attachment B3).

The following is an excerpt from the State of New Mexico HWFP (2003; Attachment B3, Section B3–9):

[8]Polychlorinated biphenyls are no longer listed in the HWFP as prohibited items; however, DOE is required to track their presence according to EPA's authorization for WIPP operation as a chemical waste landfill.

[9]In the case of newly generated wastes, it is likely that the generators' quality assurance programs will be approved by WIPP prior to generation of the waste.

To ensure that the acceptable knowledge process is consistently applied, the Permittees shall require sites to use the following definitions when complying with the data quality requirements for acceptable knowledge documentation:

- Precision—Precision is the agreement among a set of replicate measurements without assumption of the knowledge of a true value. [...]
- Accuracy—Accuracy is the degree of agreement between an observed sample result and the "true" value. The percentage of waste containers, which require reassignment to a new waste matrix code, and/ or designation of different hazardous waste codes based on the reevaluation of acceptable knowledge and sampling and analysis data will be reported as a measure of acceptable knowledge accuracy. [...]
- Completeness—Completeness is an assessment of the number of waste streams or number of samples collected to the number of samples determined to be useable through the data validation process. [...]
- Comparability—Data are considered comparable when one set of data can be compared to another set of data. Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for procedures that are used to implement the acceptable knowledge process. [...]
- Representativeness—Representativeness expresses the degree to which sample data accurately and precisely represent characteristics of a population.

There is great variability in AK accuracy (degree of agreement between observed measurements and the "true" value) among sites. AK accuracy is calculated by comparing the EPA hazardous waste identification numbers (see the Glossary) determined by confirmation activities to those predicted by historical information. A recent DOE report documents AK accuracy results for waste from the Rocky Flats Environmental Technology Site and Idaho Engineering and Environmental Laboratory. This report shows high AK accuracy when compared to the data acquired through tests with some slight differences among sites (Kehrman and Most, 2003).[10] According to DOE, differences in AK accuracy are the outcome of the implementation of inadequate procedures rather than erroneous historical information. Therefore, it is unclear how AK accuracy varies among different waste streams and among different waste sites.

4.5 CHARACTERIZATION COSTS

DOE provided the following characterization cost information at the committee's request. According to a 2000 estimate in DOE's National TRU Waste Management Plan, the total cost of waste management beginning in 2001 for the generator sites is $6.2 billion (DOE-NTP, 2000). These estimates do not include costs for work done prior to 2001. The predicted cost from 2001 of characterization and certification of both CH-TRU and remote-handled TRU waste is about $3.1 billion, or approximately 50 percent of the total budget for all sites. Waste characterization at the current level represents 16 percent of the estimated total WIPP costs of $19 billion (DOE-FSEIS, 1997).

Table 4.1 shows characterization activities, the percentage of containers to undergo these activities, and average cost estimates per container in the current CH-

[10]NMED observed that AK accuracy results are based primarily on waste from Rocky Flats Environmental Technology Site, part of which was sent to Idaho (NMED, 2003c).

TRU waste characterization plan. The "life-cycle cost" of an activity is the product of the "average unit cost," the total number of containers, and the fraction of containers that require the activity. Most costs of characterization activities are self-explanatory and refer to Figure 4.1. Waste certification costs include data management and audit activities. Characterization support costs correspond to site activities related primarily to container handling during characterization. The Savannah River Site was able to account for this activity separately; other sites included container handling in the characterization costs.

The table shows that, by far, the most costly procedures in the characterization program are those that involve breaching or penetration of the container (e.g., solids analysis, visual examination of retrievably stored waste, and homogeneous solids coring and sampling). The cost of TRU waste characterization to date averages approximately $3,900 per container. This estimate is based on an assessment at those generator sites that are currently characterizing and shipping waste to WIPP.

There is uncertainty and a great variability in costs of characterization activities among sites depending on the nature of waste streams and the volume (DOE-CABE, 2003). Characterization of the waste that has been shipped to WIPP has cost $160 million so far. If the cost of characterization remains the same, then characterization of all of the remaining CH-TRU waste destined for WIPP (approximately 750,000 drums) may cost up to $3 billion.

According to the cost analysis provided by DOE (DOE-CABE, 2003; page 23),

> [a]n area where costs could greatly be reduced pertains to the number of times a drum is actually moved prior to shipment to WIPP. […] It is estimated that as the characterization program matures at each site and the number of waste streams approved for disposal increases, the number of drum movements could be reduced by up to 50%.

The committee discusses below the CH-TRU characterization program and proposes some opportunities for improving its effectiveness. This discussion is reflected in the findings and recommendations in Chapter 6.

4.6 DISCUSSION: LESSONS FROM EXPERIENCE AND FUTURE OPPORTUNITIES

Shipment to and emplacement of more than 40,000 drums of TRU waste in WIPP after four years of operations is evidence of the acceptability to the regulators of the waste characterization program thus far. The opening and operation of the WIPP facility would not have been possible if DOE had not provided its regulators with sufficient information of acceptable quality, including waste characterization information. However, after four years of operations, there are lessons to be learned and, with the experience base steadily increasing as WIPP operations continue, opportunities for identifying characterization activities that are not necessary to protect human health and safety and the environment.

Determining whether there are inefficiencies in the characterization program and what improvements can be made is a complex task. To perform this task, a structured and quantitative analysis of characterization activities, coupled with operational experience, can be used to identify which, if any, characterization activity produces information that is not used in decisions concerning waste handling, transportation, or disposal and if alternatives that are more cost-effective and result in the same, or greater, level of protection of human health and the environment exist.

Table 4.1 Characterization Activities, Percentage of Containers Ultimately Emplaced in the Waste Isolation Pilot Plant Requiring Such Activity, and Average Cost Estimates

Characterization Activity	Percentage of Containers Requiring Activity	Average Unit[a] Cost (U.S. Dollars)	Average Cost per Container[a] (U.S. Dollars)
Non-Destructive Assay	100	840	840
Headspace Gas Analysis	100	620	620
Real-Time Radiography	32.8	730	240
Visual Examination/Retrievably Stored	1.2	22,500	270
Visual Examination/Newly Generated	67.2	540	360
Solids Coring and Sampling	0.5	24,000	120
Solids Analysis	0.5	63,000	310
Acceptable Knowledge	100	87	87
Drum Venting	1.8	120	2
Level II Data Management	100	160	160
Gas Generation Testing for Transportation	9	670	60
Drum Age Criterion	68.7	46	32
Segregation or Rework	30	1,400	420
Waste Certification	100	330	330
Characterization Support Activities	8	648	52
Average Cost of Characterization per Container			3,900

[a]The average unit cost is the cost to characterize a single container. The average cost per container is the unit cost averaged on the number of containers undergoing a particular characterization activity.
SOURCE: DOE-CABE, 2003.

This structured and quantitative analysis is the subject of Chapter 5 and leads to the committee's main recommendation (Recommendation 1). In addition to supporting the proposed analytical framework, operational experience can be used to identify opportunities to improve the characterization program that are operational in nature, some of which can be instituted without regulatory approval, as discussed below.

4.6.1 Uses of operational experience

While characterization information gathered to date at four sites cannot be directly extrapolated to other sites and to waste yet to be characterized, the operational experience accumulated during these first four years of WIPP activities provides a basis on which to evaluate whether improvements in efficiency and costs can be realized while continuing to protect human health and safety and the environment (see Finding and Recommendation 2). Examples of uses of operational experience to evaluate and improve the effectiveness of the characterization program are the following:

- Experience can be used to estimate the value and extent to which each characterization activity provides information that is: 1) essential to protect health and safety, 2) redundant with other activities or with historical knowledge of the waste, and 3) used to make decisions about waste handling, transportation, or disposal at WIPP. This information would be of use in the structured and quantitative analysis of the characterization program described in Chapter 5.

- Analysis of the characterization data acquired to date along with continuing the characterization of increasingly diverse waste streams could identify new opportunities to use statistical sampling (rather than 100 percent of the waste stream) or different methods to confirm AK to provide information that would be as protective of health and the environment as the current measurements (see Sections 4.6.2 and 4.6.3).
- Experience provides a basis for "know-how" transfer from one generator site to others. The application and sharing of improvements in management methods acquired at generator sites thus far can achieve cost, schedule, and worker dose reduction across the DOE weapons complex (see Section 4.6.1.1).
- Experience allows a better understanding of cost variability across the waste inventory and generator sites as well as a better understanding of the relative value of different characterization methods providing similar information (i.e., radiography versus visual examination). Understanding why characterization costs differ significantly from waste stream to waste stream and from site to site could also lead to better cost estimates for future waste streams (see Chapter 5).

Only the second of these four examples potentially leads to changes requiring regulatory approval.

4.6.1.1 Operational experience has already produced improvements in waste handling

The first four years of operational experience have already benefited waste handling operations. Characterization activities involve significant handling and intermediate storage (staging) of waste containers. Each container is subjected to multiple analyses, most of which can be the basis for rejecting a container which then has to be set aside waiting to be reworked. Some analyses require temperature control and aging of waste, and most require special equipment with limited throughput, such as headspace gas sampling and analysis. These activities require moving waste containers from one characterization operation to another or the staging of waste containers in the proximity of characterization areas. DOE refers to this handling of containers during characterization as the "dance of the drums" (DOE-CABE, 2003; page 23):

> Drums are moved multiple times for characterization for many reasons (e.g., when the drum needs to be separated from the batch because something is amiss with the data package, when a drum fails a certification test, or when the assay is problematic). The drum then needs to be set aside until the issue is resolved, or the drum is reworked. Costs at [the Idaho Engineering and Environmental Laboratory] are $18.33 per movement. Costs at [the Savannah River Site] are $21.60 per movement. Both [sites] have independently estimated that drums were moved approximately thirty (30) times in the characterization process.

At some sites, limited storage capacity and storage times (under current limitations of the generator sites' permits) result in further waste handling to and from storage areas between characterization operations.

The Rocky Flats Environmental Technology Site has demonstrated that the system for handling containers throughout the characterization process can be streamlined as workers and management gained experience. Improvements in operations developed at this site have led to improvements in cost, schedule, and worker protection (Spears, 2003). Such an improvement process might be applied advantageously at the other generator sites.

4.6.2 Different approaches for different waste streams

Transuranic wastes are generated at different times, in different ways, and have different properties and compositions. The quality of information available on each waste stream is particularly important because this information becomes part of AK and determines the extent of characterization activities necessary to confirm this knowledge. Some CH-TRU waste streams, by the nature of their generation, their physical and chemical properties, and other special circumstances can be shown not to require the entire suite of characterization activities that are currently being carried out.

Experience has shown that, in some cases, it is possible to tailor the characterization program to specific waste streams thereby adjusting the extent of confirmation activities to the quality and type of the information available (see Finding and Recommendation 3). For example, DOE has obtained an exemption from headspace gas sampling and analysis for thermally treated wastes at the Rocky Flats Environmental Technology Site. To obtain regulatory relief from NMED, DOE provided a technically defensible case that showed how this particular waste stream could not contain any volatile organic compound.

Opportunities for tailoring waste characterization to waste streams may be greater with to-be-generated waste. To-be-generated waste may be better characterized than existing waste because the characterization information can be collected at the time of waste generation under an approved quality assurance program. Future improvements in management methods, processes, and record keeping will also lead to better characterization information. Therefore, some to-be-generated waste may not require any, or as much, confirmation of the information collected about the waste.

On the other hand, existing waste streams may have less detailed information available and require extensive characterization. As more waste is characterized, it may be found that current characterization methods or technologies may be unsuitable for certain waste streams. For instance, some existing wastes may pose characterization challenges and may need a stream-specific characterization process (see for instance Sections 2.3 and 2.4).

Special characterization techniques may be needed for non-destructive examination and assay to measure gas concentrations in the storage container, to handle large pieces of equipment (e.g., gloveboxes with unique designs), or to address problems not yet encountered. Specialized operator training, new or improved equipment and facilities, special material handling and record keeping, and additional funding requirements are potential challenges that may have to be addressed. Changes to tailor the characterization program to different waste streams require regulatory approval.

4.6.3 Different qualification methods for different waste information

The confirmation-by-measurement method is applied systematically by DOE to qualify information to be used as AK, regardless of the extent of the information available or the origin of the waste. As experience continues to be gained, there may be future opportunities to take advantage of: 1) a statistical sampling program rather than 100 percent confirmation activities, or 2) the three other methods allowed to qualify AK (i.e., peer review, corroborative evidence, and qualification of another quality assurance program; see Section 4.4.2).

Applying statistical sampling rather than 100 percent confirmation to certain waste streams has already led to increases in program efficiencies. For example, as noted in Section 3.3.2, DOE has already successfully obtained a change to the HWFP that reduced the number of waste containers to undergo visual examination as a quality control check on radiography results, thereby saving more than $19 million.

The larger the number of containers included in a particular waste population to be sampled, the greater the potential increase in the program efficiency. As noted in Section 3.4, in the Certificate of Compliance application for WIPP, DOE identified 569 waste streams, while EPA sorted WIPP waste inventory by volume into 10 classes. In the HWFP, NMED identified 11 types of waste streams depending on the main matrix component. If too many streams are defined, the opportunities to use and benefit from a statistical approach are diminished because the population to be sampled within each stream is smaller. At the limit, if each container is its own waste class, no statistical method for that class can be used.

However, defining the population loosely to be all-inclusive could also be misleading. For instance, if a population to be sampled is defined to include both to-be-generated and existing waste (assuming the latter has poor historical information available), then statistical sampling methods would hardly represent the population. To ensure representativeness, the statistical sampling approach could apply to increasingly inclusive waste populations possibly followed by either decreasing sampling rates as experience is gained (and appropriate performance is documented) or increasing sampling rates if information is found to be inaccurate.

Future experience with to-be-generated waste may show that it is possible to use AK for selected wastes without the need for confirmation. This can be done by managing and recording what is put into the containers in compliance with the approved CH-TRU waste characterization plan and by following an approved quality assurance program (see Findings and Recommendations 3 and 4). Similarly, for existing waste that needs to be repackaged, if the appropriate characterization activities are performed during packaging under a regulator-approved program, they should provide AK-qualified information without the need to open containers for visual examination or headspace gas measurement.

Previous attempts by DOE to use qualification methods other than confirmatory measurements were not successful. DOE attempted to demonstrate that non-destructive assay measurements collected for safeguard reasons on a particular waste stream at the Rocky Flats Environmental Technology Site could be used as corroborating evidence or as a qualified quality assurance program in lieu of WIPP-certified non-destructive assay data.

About 4,000 drums had already been measured individually with a non-destructive assay system, which collects information on plutonium, americium, and uranium-235 for safeguard purposes. The Rocky Flats Environmental Technology Site measured the same population with a WIPP-certified system and made a statistical argument (based on the first 1,000 drums) that the total plutonium in the waste stream as predicted from the safeguards non-destructive assay was within 1 percent of that predicted by the WIPP-certified system.

EPA did not accept safeguard data as a qualifying method because the data did not provide information on all 10 radionuclides listed in the Compliance Certification Application (see Appendix C). EPA also rejected this qualifying method for containers with less than 0.5 grams of plutonium, the lower detection limit for safeguard data. Also, the New Mexico Environmental Evaluation Group notes that several measurements accepted by the DOE's internal safeguards program were found to be significantly in error when containers were re-measured using WIPP-certified instruments (EEG, 2003b).

DOE is currently evaluating opportunities for using peer review as a qualification method for existing information. For example, DOE has proposed to EPA that staff of the Los Alamos National Laboratory conduct a peer review on the sealed sources stored at this site, for which, according to DOE, extensive documentation is available. These sources also need to be repackaged before shipment; therefore, the information collected during repackaging, along with peer review of historical knowledge, may not need any confirmation by measurement. Changes to confirmation activities require regulatory approval.

4.6.4 Importance of effective communication

Experience shows that stakeholders,[11] not only in New Mexico, but also in states generating waste and in corridor states, have concerns about WIPP-related operations. Since 1971, when local officials in Carlsbad began advocating the development of the nation's first underground waste disposal facility in their area, local and state officials, citizens, and organizations have been involved in policy making about the WIPP site (Fleck, 2002). As plans for a repository advanced, interest in WIPP expanded to include officials and citizens along potential waste transportation routes in other regions of New Mexico, in states where DOE production facilities are located, and along transportation corridors.

Although there has been broader public acceptance of the WIPP facility over time,[12] there continue to be concerns about characterization-related activities and transportation (SRIC, 2001a; UNM, 2001; Daniels, 2003). Members of the public are concerned about DOE's reliability in adequately protecting human health and safety, particularly in the event of an accident. Concerns about transportation include the use of uncertified characterization procedures; the safety of shipping containers; and the safety of transportation routes. A transportation protocol agreement has been signed between DOE and some of the corridor states reflecting the desire to ensure safe and uneventful shipments of waste to WIPP (see Sidebar 3.1).

During open meetings in Carlsbad and Santa Fe, the committee heard concerns about waste characterization from members of stakeholders organizations[13] including the following:[14]

- Rationale for proposed permit modifications is lacking (Nuclear Watch of New Mexico, 2003).
- DOE permit modification requests are frequent and of poor quality (SRIC, 2002; Petrie, 2003).
- There is a lack of transparency in the decision-making process (SRIC, 2001b; Arends, 2003; Hancock, 2003; Petrie, 2003; Reade, 2003).
- Internal drivers for DOE's cleanup program may lead to a reduction in characterization activities necessary for protecting public and worker health in order to save money (Petrie, 2003).
- Less stringent characterization activities could increase potential radiation doses received by the public (Reade, 2003).

[11]The term “stakeholders” indicates local officials and interested and affected members of the public in New Mexico, waste generator states, and corridor states.

[12]The University of New Mexico has been tracking public opinion since 1990 (UNM, 2001).

[13]As others have noted, most people who comment publicly about WIPP in New Mexico are members of existing stakeholder groups (Phoenix Environmental and Envirolssues, 2001; Drew et al., 2003).

[14]The committee's understanding of the concerns of citizens and officials about characterization activities is based on presentations to the committee and on published documents (e.g., public comments on HWFP modification requests), not on an independent study conducted by the committee.

- Changes to the waste characterization program may result in a decrease of regulatory authority by EPA and NMED (Petrie, 2003).

Communities near generator sites are concerned about risks to site workers; risks of storing waste at the sites; costs; and delays in moving waste out of their sites. Representatives of Citizen Advisory Boards from nine DOE sites prepared the following recommendations for DOE during a recent conference on TRU wastes (CAB, 2003):

- Characterize TRU waste as required to reduce risk and minimize transportation and handling of the waste, while making the process cost-effective.
- Streamline TRU waste management by accepting demonstrated process knowledge for TRU waste characterization.
- Evaluate the concept of one or more locations to characterize TRU waste for WIPP disposal.
- Finish the analyses and make a decision with adequate public involvement regarding where to characterize TRU waste for disposal.

Several law suits against DOE involving generator or corridor states on matters related to WIPP were filed in 2003, reflecting local group's concerns with the shipment and storage of out-of-state wastes to their site (Ashton, 2003; Mulick and Stang, 2003). For example, in Washington State, there was concern about the Hanford Site receiving TRU wastes from the Battelle Columbus Laboratories site in Ohio for characterization before being shipped to WIPP (Mulick and Stang, 2003; Stang, 2003). The state filed a lawsuit against DOE to reach an agreement on an accelerated shipping schedule for Hanford waste to WIPP, in exchange for storing and characterizing waste from other sites.[15]

Experience has shown that effective, transparent communication and the use of the established regulatory processes to make changes to the characterization program can help build cooperation and confidence among all parties (see Finding and Recommendation 5 and 6). The lack of public accessibility to characterization records and the WIPP Waste Information System database is a frequently-expressed concern among stakeholders. WIPP stakeholders have also publicly commented on the lack of information on proposed changes to the characterization program. Records of changes to the WIPP program show that regulators granted modifications to the authorization documents only after extensive communications and data exchanges with DOE staff, and after DOE provided a defensible technical analyses to show that proposed changes do not weaken protection of the human health and safety and the environment (see Section 3.3).

The New Mexico Environmental Evaluation Group's independent evaluations have contributed in building effective communication and transparency. This group provides technical input and oversight to DOE about WIPP issues, including transportation, and helps in conveying technical information to stakeholders and the general public. The quarterly meetings between DOE, NMED, the New Mexico Environmental Evaluation Group, the New Mexico Office of the Attorney General, and interested members of the public are an example of DOE's efforts to maintain communications and address concerns. Changes in the communication and outreach efforts of the program do not require regulatory approval. Experience in other waste

[15] An agreement was reached in October 2003 by establishing a legally binding schedule for the removal of TRU waste from the Hanford Site in exchange for accepting TRU waste shipments from Ohio.

disposal programs has shown that effective communication with stakeholders and regulators as well as transparency can help to reduce or mitigate the lack of trust, avoid charges of secrecy, and possibly lead to greater tolerance of changes, where warranted (NRC, 2003 and references therein).

Using operational experience is only one of the keys to improving the program. The uniqueness of certain sites or waste streams does not always allow taking advantage of past experience. Moreover, changes to the characterization program may have policy or societal impacts that need to be considered prior to submitting a permit modification request. A structured and quantitative analysis of the linkages between risks, benefits, and impacts of characterization activities along with analyses of past and future waste inventory characteristics is needed to arrive at a flexible waste characterization plan program that can take into account the variability of sites and waste streams, allowing for more efficient and effective waste characterization operations as well as communication among all parties (see Findings and Recommendations).

5

A Framework for Evaluating Waste Characterization Activities

In this chapter, the committee describes the elements of an analytical framework to evaluate the effectiveness of specific characterization activities by relating the information gathered through waste characterization to the benefits it produces. The chapter ends with simplified illustrative applications of the proposed framework.

5.1 STATEMENT OF THE PROBLEM

The U.S. Department of Energy's (DOE's) contact-handled transuranic (CH-TRU) waste characterization program is controversial. DOE as well as the New Mexico Environmental Evaluation Group (EEG) and previous National Research Council committees have suggested that some characterization activities are too extensive, costs are too high, and some of the information gathered is not used to make any decision related to the protection of human health and safety or the environment. On the other hand, stakeholders in New Mexico have argued that all the current characterization activities are necessary to ensure an adequate level of protection.

DOE has informed the committee of its intention to propose changes to the characterization program to eliminate or modify activities that do not have an impact on human health and safety or the environment. However, as discussed in Section 5.3, DOE did not provide the committee with a formal analysis of the impacts of altering specific characterization activities on costs or on risks to the public, workers, or the environment.

DOE is responsible for making the policy decision to seek regulatory approval for changes to a particular characterization activity. In the committee's view, a structured and quantitative analysis is necessary to determine whether a change to the characterization program is warranted and to justify proposed changes with the regulator (s), state and local officials, and the general public (see Recommendations 1, 5, and 6 in Chapter 6). In this chapter, the committee provides the elements and illustrative applications (albeit incomplete) of a proposed structured and quantitative analytical framework that could be used to evaluate changes to specific characterization activities.

5.2 AN OVERVIEW OF A PROPOSED ANALYTICAL FRAMEWORK

Below, the committee presents the elements of a generic analytical framework that could be used to identify changes to specific characterization activities. The purpose of the proposed analytical framework is to determine the value of the characterization information obtained through a given characterization activity. If the information is used to make decisions about waste handling, transportation, or disposal, then it has an impact on the outcome of these decisions (for instance, on reducing risks, uncertainties, costs, or delays), and thus it has value in the present context. On the other hand, if the characterization information is not used in current or future decisions, then it has no impact, and therefore it has no value. These are the two extremes. In most cases there is some value,[1] but the question is whether costs to obtain the information exceed the benefits it produces.

Figure 5.1 shows a general flow diagram of the characterization and decision-making process. Boxes represent decisions by DOE, such as the decision to review a characterization activity in the current characterization program or to request a permit modification for the Waste Isolation Pilot Plant (WIPP). Ovals represent outcomes of these decisions. The current waste characterization program is composed of characterization activities (see Section 4.1) that generate a flow of information about the wastes. Some of this information is used to make decisions, such as whether to remove prohibited items or to vent a canister prior to transportation. The characterization activities, along with the decisions made on the basis of the information gathered, lead to impacts in terms of risks to workers and the public, costs, and public concerns.

Feedback loops represent updating and improving characterization activities through experience, data collection, and analyses. Experience and learning lead to ideas for improvement, by eliminating unnecessary characterization activities, finding more cost-effective[2] solutions, or by adding activities to further reduce possible risks. Once these possible improvements are identified, they form the basis for a permit modification request, which is submitted to the appropriate regulatory agency. The regulatory agency decides whether the proposed change is still in compliance with the regulations and approves or declines request. Within this framework, DOE would communicate interactively with stakeholders about proposed changes to the program and stakeholders would provide input. Stakeholder input could be provided informally during public information exchange meetings (such as the WIPP's quarterly meetings), or formally, through a public comment period during the regulatory process. Stakeholders concerns are part of DOE's analysis to determine whether a permit modification is warranted (see Section 5.6).[3]

Within this framework there are several opportunities for structured and quantitative analyses of the value of the characterization information. First, in applying this framework, the characterization information could be recorded and analyzed to determine how the characterization information is used and whether it is used frequently, rarely, or never. For example, information on volatile organic compounds (VOC) or instances of identified prohibited items in waste drums could be recorded and its impact on decisions to vent canisters or to remove prohibited items could be analyzed.

Second, the impacts of the characterization information on the decisions made on the basis of this information could be analyzed in terms of their combined impact on risks, costs, and other aspects of the characterization program. For example, the risks of transporting canisters with high VOC levels or with prohibited items could be analyzed to determine the risk reductions achieved by characterization. By comparing risks, costs, and other impacts, such as policy and societal impacts, with and without characterization information, the proposed analytical framework can establish the value of characterization information.

Similarly, this analysis can support proposed changes to the characterization program by showing that alternative characterization activities are more cost-effective than the current ones. The analytical framework proposed here derives from a decision-analysis

[1]For example, characterization information is used in preparation and archiving of a record of characterization activities and may have value in that context.

[2]For a definition of cost effectiveness, see Section 5.7.

[3]Mechanisms for stakeholder participation in decision-making have been discussed by other National Research Council committees (NRC, 2003 and references therein).

tool called the Value of Information.[4] Other analytical approaches have elements in common with the proposed framework, such as the Data Quality Objectives approach proposed by the U.S. Environmental Protection Agency (EPA) (2000).

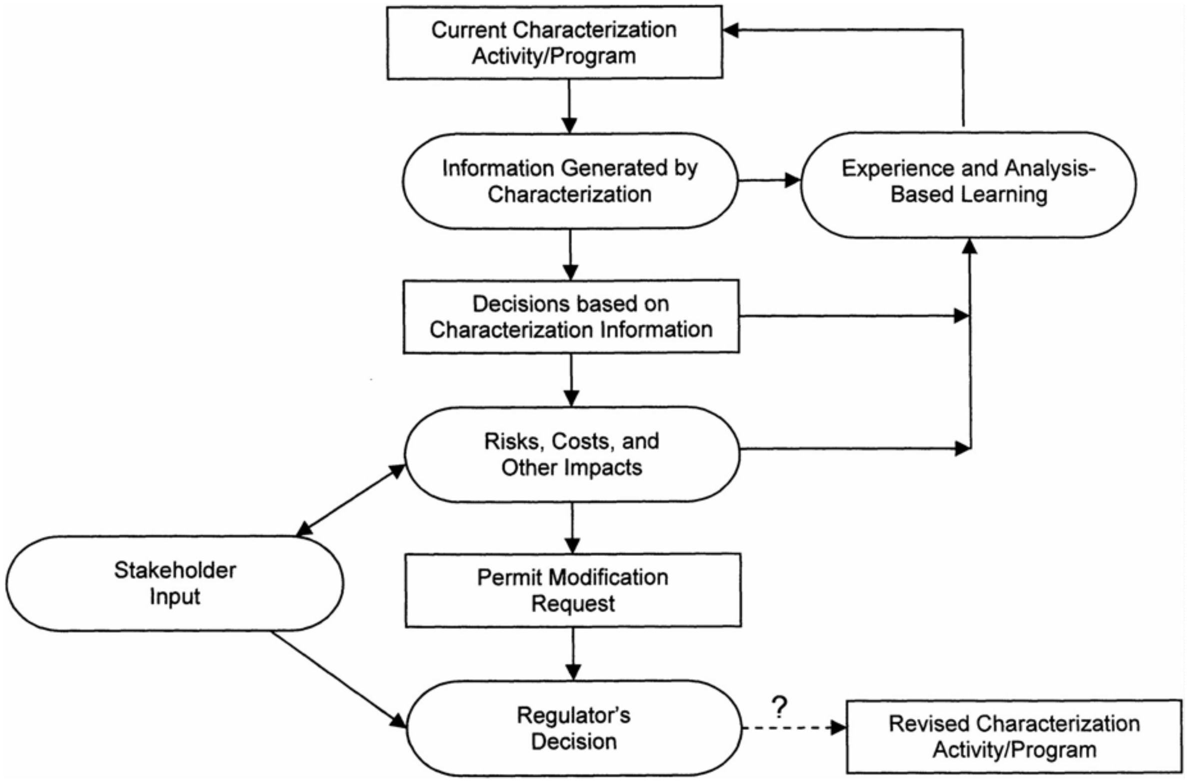

FIGURE 5.1 Features of the proposed analytical framework. Boxes represent decisions; ovals, outcomes; and arrows, the dependencies between them. The dotted line indicates uncertainty in the regulatory decision. The double-headed arrow represents interactive communication. For an explanation of the figure, see text.

An analysis of the effectiveness of characterization activities addresses not only risks and costs, but also programmatic impacts (e.g., delays in processing wastes) and policy and societal impacts (e.g., need for an authorizing document modification request or a shift in public perception due to a change to the program). These impacts and suggestions for how to address them within this analytical framework are discussed below.

5.3 ASSESSMENT OF THE RISKS

The first type of analysis in the proposed analytical framework is risk assessment. In the present context, the purpose of risk assessment is to determine the link between waste characteristics and risks related to handling, transportation, and disposal of CH-TRU waste at WIPP. The assessment of risks takes into account risks at a "micro" level (e.g., risks to workers gathering characterization information) and at the "macro" level of the National TRU Waste Management Program (e.g., risks incurred at

[4]For example, see Clemen and Reilly (2001); Winkler (2003); and, for an application to the characterization of Hanford tank wastes, see Fassbender et al. (1996).

the site, during transportation, and at the WIPP facility). Non-technical risks, such as the risk of decreased public confidence, are also important in the proposed analysis.

Waste characteristics that affect health and safety are the most important to characterize. If a characterization activity produces information on waste characteristics that are not linked to human health and safety or the environment, then there are no programmatic decisions to be made with respect to those characteristics.

The risk assessment also determines the accuracy and precision needed in knowing a given piece of characterization information. Uncertainties in each analytical measurement are considered and propagated through the analysis so that risks are weighted by the propagated uncertainties. Each estimate of risk therefore has an uncertainty assigned to it. Risks with large uncertainties indicate that those characterization activities that define that risk need more consideration and attention unless the risks themselves are of little consequence. Such an analysis may indicate that more characterization is needed or that different characterization activities should be explored. Estimates of risks for which the uncertainties are small indicate that a higher degree of confidence exists for those parameters, and perhaps less analytical data are needed or could be justified.

When assessing risks and how they are impacted by characterization information, it is important not only to consider routine and expected situations, but also to inquire how the characterization information might be used in unusual and unanticipated or low probability circumstances. Several situations in which characterization data could be valuable can be envisioned. For example, if waste emplaced in WIPP must be retrieved, characterization information might become useful. In addition, different or additional characterization information may become useful for future, as yet undefined, waste streams. Risks in accident conditions would take into account the probability and magnitude of the consequences for each accident scenario in which characterization information could be useful.

DOE has prepared several analyses containing elements of risk assessments that were submitted to WIPP's regulatory agencies to authorize operations at the WIPP facility. For instance, the EPA Certificate of Compliance relies on an evaluation of a performance assessment which includes elements of risk assessment (DOE-CCA, 1996). The Land Withdrawal Act requires an analysis of the environmental impact of WIPP operations (DOE-WAC, 2003) and a Safety Analysis Report[5] (DOE-SAR, 2003). DOE has also conducted safety analyses and performance assessments in connection with transportation of wastes to WIPP (DOE-SARP, 2003). Many of these studies are now being updated to reflect recent data and experiences and are periodically reevaluated.

Although DOE has performed analyses of many aspects of operations related to WIPP performance, including transportation, the committee could find no studies that explicitly, systematically, and quantitatively link its waste characterization program to risks to the public, workers, or the environment (see Finding and Recommendation 1). In particular, DOE has not used the studies mentioned above to estimate quantitative relationships between current or planned characterization activities and risks. DOE

[5]The WIPP Safety Analysis Report, required by agreement with the State of New Mexico, documents the adequacy of safety analysis to ensure that a facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations. The report is based on the facility's safety analysis, which is a documented process that: 1) provides for the systematic identification of hazards within a given DOE operation; 2) describes and analyzes the adequacy of measures taken to eliminate, control, or mitigate identified hazards; and 3) analyzes and evaluates potential accidents and their associated risks.

provided cost information for ongoing characterization activities but the committee could not find any discussion of the costs and benefits of current characterization activities compared to alternative ones.

The committee is not aware of any analysis showing the risks of handling, transporting, or of disposing of some of the prohibited items listed in the Hazardous Waste Facility Permit (HWFP). Such items are currently handled by workers when they are identified in waste characterization and removed from waste streams to attain compliance. To the best of the committee's knowledge, DOE's risk assessments address only waste characterized in compliance with Waste Acceptance Criteria and HWFP requirements. In these risk assessments it is assumed that waste characteristics are known based on the current characterization program. For instance, the performance assessment submitted for EPA Certification is based on the assumption that waste activity and volume are within the limits established in the Land Withdrawal Act and that the waste does not contain any water or other prohibited items.

Only recently (September 2003) has DOE submitted to the committee studies that could be viewed as the initial elements of an analytical approach in connection with a request for a change in the headspace gas sampling-related activities (Boatwright, 2003; Myers, 2003; and McCulla and Van Soest, 2003). These studies include an evaluation of WIPP room-based VOC monitoring as an alternative to analyzing the headspace gas of each drum. Additional material submitted address Data Quality Objective-related issues, and the accuracy of Acceptable Knowledge (AK) on waste characterized to date (HWFP, 2003; Kehrman and Most, 2003).[6]

Examples of issues to be included in the proposed analytical framework to determine the linkage between waste characteristics and risks in handling, transportation, and disposal of CH-TRU waste at WIPP can be found in Appendix F. Risks considered are the following:

- risks related to waste handling;
- risks related to transportation; and
- risks related to waste disposal.

Within its constraints of time and information, the committee could only point out some of the risks to be included in this analysis; a complete risk assessment is a major endeavor that the committee was not prepared to undertake.

5.4 COSTS OF WASTE CHARACTERIZATION

Analysis of the impacts of waste characterization on costs would include “hard” as well as “soft” costs. Hard costs are the costs associated with gathering characterization information. Table 4.1 shows that the most expensive characterization activities involve breaching waste containers and waste analyses. This is due to the costs of protecting workers from radiation. Other hard costs include: costs of equipment, data management, overhead costs (including that for quality assurance), characterization method certification, staff training, record keeping, as well as the costs of submitting a permit modification.

Soft costs are costs that are difficult to quantify, such as the costs associated with a possible loss of stakeholder confidence; the costs of delaying shipments to WIPP if the permit modification request is denied; or costs incurred in the case of an accident

[6]NMED found that these analyses lack correlation between the characterization issues associated with waste emplaced to date and the remaining inventory projected for disposal at WIPP (NMED, 2003c).

(e.g., costs of cleanup if reduced characterization information leads to an accident during waste handling, transportation, or disposal).

According to DOE's cost analysis, it is not possible to predict whether characterization costs will increase or decrease with time:

> A comparison of the unit costs developed [between October 2002 and June 2003] showed no significant trend (either up or down) for unit costs over time. While some costs did in fact decrease, others increased. Many factors impact the costs, some of which cannot be controlled, or reduced, at the activity level. In some cases, a reduction in quantities may even lead to an increase in unit cost.
>
> Site-specific priorities such as stakeholder interaction, or regulatory impacts, directly impact unit costs. Increases or decreases in facilities and infrastructure costs affect the cost structure relating to characterization activities. Sites differ in the types and amounts of TRU waste, schedules for shipping, contractual agreements for characterization, and the maturity of the program. All of these factors, whether positive or negative, affect the total costs. While processes may be streamlined and shipping procedures made more efficient, costs may not be reduced proportionately. Therefore, reducing future costs must be pursued in other areas, such as regulatory relief and technology development (DOE-CABE, 2003; page 23).

The committee believes that, as the experience base continues to grow, it is possible to analyze costs sufficiently to produce at least a credible and useful prediction of cost trends under the most likely scenarios. Changes to the characterization program that would improve the characterization process, together with an expanding operational experience base, could help reduce both risks and costs. However, if new and more difficult or complex waste types have to be dealt with in the future (see Sections 2.3 and 2.4), or more stringent cleanup standards are imposed by the regulators, then characterization costs could increase.

Scenarios in which characterization needs and costs may increase are the following:

- radiographic techniques and other special characterization techniques and technologies for large containers may have to be developed and may cost more than the observed costs to date;
- remote-handled transuranic waste with dose rates greater than 1,000 rem per hour may be authorized in WIPP possibly requiring additional worker protection measures;
- previously buried TRU wastes may include more compromised containers requiring more elaborate handling procedures;
- future waste streams may require new or different characterization information;
- additional TRU waste not accounted for in current inventories may be approved for disposal in WIPP increasing total characterization, transportation, and disposal costs; or
- characterization requirements may be added or strengthened for public confidence purposes, in particular if an accident occurs.

Changes to the characterization program also have an impact on the schedule. The proposed analytical framework would consider time and effort required to: acquire alternative characterization information (to the required accuracy and precision); manage the data (including quality assurance activities at the data generation level and project management level); prepare a permit modification request; obtain approval of the modification, obtain certification; and train personnel to use new characterization equipment.

5.5 POLICY IMPACTS

Most[7] changes to the characterization program must be approved by the regulator(s) to ensure continued regulatory compliance. Regulatory compliance is grounded in risk considerations. Regulatory requirements are derived from assessments of the risks to the public, workers, or the environment and the need for records documenting waste characteristics, waste characterization activities, and oversight of related operations. Therefore, while characterization is not a risk assessment in itself, its purpose is to provide information used in determining if criteria derived from risk assessments have been met.

DOE and its regulators worked to translate the intent of various environmental laws (such as the Land Withdrawal Act, the Resource Conservation and Recovery Act) into specific regulatory requirements for waste characterization. These regulatory requirements are set forth in 40 CFR 194, the HWFP, and the Certificate of Compliance for transportation packages (see Chapter 3 and Appendices C and E).

The details of characterization activities are prescribed in WIPP's Waste Acceptance Criteria and in the HWFP. The Waste Acceptance Criteria can be modified without regulatory approval if changes are not in conflict with EPA, New Mexico Environment Department (NMED), or U.S. Nuclear Regulatory Commission (USNRC) regulations; any change to the HWFP has to be approved by NMED.

Experience shows that requests for authorization document modification are most likely to be approved if they are supported by careful analysis and detailed records of characterization experience. As a result of substantial interactions with the regulators and thorough technical justification in specific areas, DOE has succeeded in obtaining many revisions of the WIPP program thus far (see Chapter 3).

The political feasibility of a change in the characterization program is a further element to be considered in the impact analysis. The HWFP is the only direct control that New Mexico has on the characterization process and WIPP operations. Any proposed change to the characterization program will be examined carefully by the state with regard to its effects on previous agreements and on the state's role in regulating WIPP.

Moreover, continuing to use the established regulatory processes for making changes to the characterization program could help build cooperation and confidence among all parties (see Finding and Recommendation 6). The proposed analytical framework could be used to make a technically defensible case before the regulator and the public that a given change to the program is still protective of human health and the environment. The regulator would make the final determination whether the proposed change would still lead to compliance with regulations.

[7] Some changes to characterization activities are under DOE's purview, such as the addition of fast-scan radiography at the Savannah River Site to screen for prohibited items (see Section 4.3).

5.6 SOCIETAL IMPACTS

Although societal impacts are difficult to quantify, the impact of a change to the characterization program on stakeholder confidence in DOE, not only in New Mexico, but also in generator and corridor states, cannot be ignored (see Findings and Recommendations 5 and 6). The public, state and tribal officials, and organizations such as the Western Governors Association and citizen's groups watch the permit modification process closely. Evidence suggests that some members of the public and state officials lack trust in DOE. Some stakeholder concerns are listed in Section 4.6.4.

Unless supported by technically defensible analyses showing that no increase in health, safety or environmental risk will ensue, a request for change in a permit may be interpreted as leading to a decrease of safety, with concerns of increased risk to workers, the public, and the environment.

Changes to the characterization program that would accelerate waste shipment to WIPP (or elsewhere) may be popular at generator sites from which the wastes would be removed. However, they may have a negative societal impact in the recipient state, New Mexico, or in corridor states through which waste is transported, if it is believed that such acceleration reduces safety.

Providing a defensible and credible technical analysis and characterization record to the public in support of programmatic changes could build confidence that the changes do not weaken protection of human health, safety or the environment, and help avoid charges of secrecy that might otherwise be made. Characterization information could be disseminated in a variety of ways, including through published reports, public access to the WIPP Waste Information System, or summaries thereof.

The analytical framework proposed by the committee, or any comparable analysis produced in an open and responsive process, can help reduce or mitigate any lack of trust and lead to greater tolerance of changes, where warranted. The societal impact of changes to the program, provided they are technically defensible, may even be positive overall in light of savings in taxpayer dollars.

5.7 COST-EFFECTIVENESS ANALYSIS

To determine whether a characterization activity has value, information on the risks, costs, and other impacts with and without the characterization activity is needed. For example, to determine the value of headspace gas sampling and analysis and how it reduces risks, data on the flammability and risks of worker exposure to high VOC concentrations if headspace gas sampling did not occur are necessary.

There is a simple rule to identify which characterization activity needs to be reevaluated through a structured and quantitative analysis: if the information gathered by this activity is never used for making decisions about waste handling, transportation, or disposal, it has no value. This is because the risks, costs, and other impacts of this characterization activity would be the same without collecting this information. Ultimately, the choice of modifying or eliminating a characterization activity from the program depends on a cost-effectiveness analysis.

Proposed changes to current characterization activities could be justified by clearly demonstrating that the changes improve the program in the following ways:

1. the proposed change is less expensive, involves less worker risks, less public risk, and less other impacts than the current characterization activity;
2. the proposed change is less expensive or has less worker risks or both and has the same public risks and other impacts than the current characterization activity, particularly if the current characterization activity generates information that is not used for decision-making purposes; or

3. the proposed change costs much less or has much less worker risk or both and affects public risk and other impacts in a minor way.

The first case is the most convincing one: there is no reason to reject a change that is better in all aspects. The second case involves a cost-benefit analysis that determines whether it is possible to obtain the necessary information for less cost and worker exposure. The third case is the most complex one, since it requires quantification of the terms “much” and “minor,” which is usually done in a cost-effectiveness analysis.

A cost-effectiveness analysis differs from a cost-benefit analysis in that the former relates the money spent to the benefit (in whatever units) gained, while the latter requires that all costs and benefits be expressed in monetary terms. Cost-effectiveness does not require monetization of “effectiveness,” just quantification of a measure of effectiveness. Cost-effectiveness quantifies all costs as direct costs and all benefits or effectiveness measures in non-monetary terms. This allows making judgments about whether it is worth spending an incremental amount of money for an incremental amount of “effectiveness” without assigning dollar values to the effectiveness measure. In this context, a cost-effectiveness analysis allows assessment of a broader range of impacts (including soft costs, policy, and societal impacts) without attaching monetary values to them.

5.8 IMPLEMENTATION CONSIDERATIONS

The proposed analytical framework is conceptually powerful, but demanding in practice. A technically complete, formal cost-effectiveness analysis, as defined in risk and decision analysis, requires a “well-defined problem.” That is, the decisions and outcomes are defined, an appropriate “measure of value” for the problem is specified, the relevant measurable parameters are identified, and the degree of certainty or knowledge about each of these is quantified. The complete and formal application of such an analysis requires that: first, the connections between waste characterization and impacts to workers, the public, and the environment be identified; second, that actual information about risks, costs, worker exposure, and benefits of characterization information be available; and third, that all consequences (environmental, health, programmatic, policy, and societal risk, costs, and benefits) be converted into a single number specifying equivalent cost or utility.

Given its complexity, a complete analysis of the benefits and costs of each waste characterization activity is beyond the committee's capability in this study. In any event, neither DOE nor the regulators provided any information on the linkages between characteristics, waste characterization activities, and protection of human health and environment. The committee also had limited information on worker doses associated with some specific activities. Absent the linkages between waste characterization and system performance, the committee could not identify specific changes to characterization activities.

To identify the most promising areas in which to evaluate the effectiveness of the characterization program, a less elaborate analytical framework than the one described above can be used. If an alternative characterization activity is compared to the current one, and the alternative is found to be better from the point of view of risk and cost and at least equal on all other parameters, then these activities are candidates for a quantitative cost-effectiveness analysis.

5.9 APPLICATIONS

Based on the information provided by DOE and on findings by a previous National Research Council committee, three characterization activities appear to be candidates for re-evaluation using the proposed analytical framework:

1. headspace gas sampling and analysis;
2. homogeneous waste sampling and analysis; and
3. visual examination to confirm radiography results.

According to the information gathered by the committee, these three characterization activities are carried out with their current sampling frequencies mainly for regulatory compliance and do not appear to directly reduce risks or costs. These activities could be analyzed through the proposed analytical framework to determine their value and impacts, and whether there are alternative characterization activities (or modifications to the current one, such as different sampling frequencies) that would still be in compliance with regulations and whose risks and costs to gather the information would be more commensurate with the risks entailed. If the alternative has positive impacts on risks and costs, as well as on policy and societal factors, then DOE may decide to apply for a permit modification.

For each example below, the committee attempts to analyze the value of the characterization information qualitatively. The information and conclusions provided are based on information gathered during the study. Different, more appropriate examples might become evident if a more complete risk and impact assessment were implemented.

5.9.1 Headspace gas sampling and analysis

Headspace gas sampling and analysis was chosen as an example on the basis of information submitted by DOE, on cost considerations, and on the findings of a previous National Research Council committee. Although not the most expensive activity per unit cost, headspace gas sampling and analysis is one of the most expensive activities when averaged on the entire waste inventory because it involves sample collection and analysis on 100 percent of waste containers. During information gathering meetings, DOE has publicly stated that this activity is performed only to ensure compliance with the HWFP.

A previous National Research Council committee found that there was no specific regulatory requirement in the Land Withdrawal Act, the Resource Conservation and Recovery Act, or in 40 CFR 264 to sample headspace gases in the totality of waste. DOE proposed to NMED to do so while drafting the HWFP application (NRC, 2001). NMED accepted the proposal and this characterization activity is now codified in the HWFP and therefore has become a regulatory requirement. The HWFP now mandates that the concentration of 29 VOCs be measured in all drums (see Section 4.3 for exceptions) before shipment to WIPP to ensure that their concentration in WIPP waste disposal panels is within the limits allowed in the HWFP.

The alternative characterization activity considered by the committee is room monitoring in WIPP for VOCs coupled with flammability tests at generator sites for compliance with transportation regulations. The suitability of this alternative activity could be periodically checked by headspace gas sampling and analysis on a statistical basis. VOC concentrations in WIPP are currently monitored in WIPP's exhaust shaft, as required in the HWFP, to confirm the absence of VOC release into the repository.

5.9.1.1 Assessment of risks

This characterization activity is designed to help assess risks from the presence of VOC in WIPP above the allowable limits, presence of flammable gas above flammability limits during shipping and handling drums in WIPP, and presence of hazardous compounds in WIPP not identified with AK. The objective of headspace gas sampling and analysis is to prevent shipment of flammable or explosive gases, exposure of WIPP workers to VOC concentrations above applicable limits, and VOCs release in the atmosphere. Room sampling would measure directly VOC concentrations in WIPP.[8] Flammability limits could be tested at generator sites using alternative characterization methods to track hydrogen and methane (for example using gas chromatography with a flame ionization detector).

The proposed alternative characterization activity would produce equivalent risk information in a potentially more reliable fashion. According to DOE, VOC concentrations measured in the stagnant air behind the curtain used to isolate each disposal room after it has been closed correlate well with results from headspace gas sampling and analysis at generator sites (Boatwright, 2003). Therefore, this method could be used instead of headspace gas sampling and analysis at generator sites. However, the information would be at a different level of specificity, as current headspace gas sampling and analysis provides data on each drum, while room sampling would not identify individual container sources for any VOCs detected.

5.9.1.2 Value of characterization information

The concentrations of the 29 VOCs in each drum are used to project VOC concentrations in WIPP and to confirm AK by comparing the VOCs found in the headspace gas to those expected from historical knowledge of the waste. In its review of CH-TRU characterization activities, the EEG writes (EEG, 2003b; page 28):

> [Headspace gas sampling and analyses] do provide additional information on the contents of waste containers. Additional waste streams have been defined because of the results of these analyses, and on occasion additional RCRA [Resource Conservation and Recovery Act] hazardous waste numbers have been added to waste streams. The importance of these functions has occasionally been denigrated, primarily because this additional information is not used to control quantities of VOCs coming to WIPP other than to show compliance with the room based concentration limits. […]
>
> This information is used (in conjunction with acceptable knowledge) to assign hazardous waste numbers to each container. However, EEG is not aware that these hazardous waste numbers are used to exclude waste from the WIPP or to otherwise control the hazardous waste. These data probably provide the incidental benefit of confirming AK and ensuring the various Waste Acceptance Criteria (WAC) requirements for stability of waste are met.

The EEG believes that it is desirable to maintain a comprehensive headspace gas sampling and analysis program for CH-TRU wastes as an additional confirmation method for AK. However, it adds (EEG, 2003b; page 58):

[8]To date, VOCs have not been observed in the exhaust shaft at WIPP, due both to the high rate of air flow through the mine and because waste received to date has contained low levels of VOCs in the headspace gas.

> it should be possible to require less than 100% sampling in some cases. Our primary concerns are with organic sludges and older waste containers where information may be less reliable.

Headspace gas data and records are also used to ensure that the concentration of flammable gases (in particular, methane and hydrogen) does not exceed flammability limits for transportation purposes. Headspace gas information affects transportation decisions (e.g., purging the container prior to transportation) and consequences (e.g., the risks and possible consequences of deflagration during transportation). The information gathered with the alternative characterization method could be used to make the same decisions about transportation as above.

5.9.1.3 Cost impacts

Details on the efforts and costs to obtain the headspace gas sampling and analysis are in Chapter 4. The sampling and analysis requires approximately 4.4 person-hours and costs, on average, $620 per waste container. Most of the characterization effort and time is due to the data management for 29 VOCs. DOE informed the committee that, although reliable cost estimates are not available, the technical effort to obtain hydrogen and methane concentrations through gas chromatography using a flame ionization detector is similar, in terms of equipment and time, to that for VOCs (Nelson, 2003). However, the data management effort is substantially lighter because there are only 2, rather than 29, VOCs to track. The same quality assurance requirements apply to the monitoring of VOCs in WIPP, as established in the HWFP.

5.9.1.4 Policy impacts

Any change to the headspace gas sampling and analysis activity requires a HWFP modification. In several occasions, NMED has stressed the importance of this characterization activity to satisfy the regulatory requirement of 40 CFR §264.13(a)(1) to "obtain a detailed chemical and physical analysis of a representative sample of the wastes" before such waste is accepted for disposal. NMED has provided comments to the committee on the DOE's analyses supporting the request for relief from this characterization activity. According to NMED, DOE did not go far enough in the analysis of the relationship between VOC data of waste emplaced thus far and those of future waste streams (NMED, 2003c; cover letter):

> [the conclusions reached in the AK accuracy analysis] do little to address the uncertainties associated with older, poorly documented waste streams generated fifteen to thirty years ago that have yet to be characterized.

The committee believes, based the information it has received, that the proposed alternative can be shown to be in compliance with regulations and to ensure the same level of protection of human health and the environment as the present characterization activity. Should VOC concentrations measured in disposal rooms begin to rise, steps (e.g., increasing ventilation rates) can be taken to control worker exposure or releases to the atmosphere. Concerning the policy impacts on transportation requirements, flammability characteristics of waste can be monitored by any method or equipment that complies with the quality assurance requirements (calibration, records, training, and so forth) listed in the Quality Assurance Program Plan.[9] However, a change in the flammability test may require a modification to the USNRC Certificate of Compliance for shipping containers.

5.9.1.5 Societal impacts

According to the records of public comments to HWFP modifications, stakeholders in New Mexico have reacted strongly to proposed changes to the headspace gas sampling and analysis requirement. Their concern is that any change to this requirement could jeopardize the protection of human health and safety and the environment (Nuclear Watch of New Mexico, 2002). A change to this requirement, if not fully supported by a structured, credible, and quantitative analysis, could cause a loss of confidence, in particular in the case of an accident involving VOCs or hazardous waste components that were not detected prior to shipping the waste to WIPP. Corridor states also need assurance that the proposed alternative does not increase transportation risks.

5.9.1.6 Cost-effectiveness analysis

The following cost-effectiveness analysis for this characterization activity is only qualitative and is based on partial information received by the committee during this study. The purpose is simply to illustrate the use of the value of information framework in a structured and quantitative analysis of characterization activities. Based on the comparison between the status quo (headspace gas sampling and analysis) and the proposed alternative, it appears that the information on VOC concentrations obtained at generator sites is redundant with that obtained through WIPP disposal room monitoring, could potentially be less reliable, could be obtained with a cheaper alternative, and therefore has low value. In other words, the value of the information gathered with the proposed alternative appears to be higher.

In situ monitoring coupled with measurements of hydrogen and methane at generator sites for transportation regulation purposes is a more cost-effective solution that could ensure the same, or a potentially higher level of protection of human health and the environment. Moreover, the committee believes that EEG and NMED concerns with organic sludges and older waste containers can be addressed with the proposed alternative.

To decide whether a permit modification would improve the program a more complete analysis is needed in which the advantages of using the alternative characterization activity are considered along with the cost, time, and effort to prepare a permit modification request to NMED (and possibly a USNRC Certificate of Compliance modification), as well as with the risks of decreasing the confidence of the public in New Mexico and that of corridor states in the safety of WIPP operations.

5.9.2 Homogeneous waste sampling and analysis

Homogeneous waste sampling and analysis is the most expensive unit characterization activity even though it applies to only a small fraction of the waste (see Table 4.1). A previous National Research Council wrote the following about this requirement (NRC, 2001; page 80):

[9]The requirements for gas testing are listed in the "Quality Assurance Program Plan for the Gas Generation Test Program" (available at <www.wipp.ws/library/gasgenqapp/DOE-WIPP-01–3187Rev1.pdf>).

> No operational decisions are made based on these data; that is, the results of the sampling and analysis do not affect how waste is handled, so it is not clear what justifies the additional radiation exposure risk and cost of this procedure. In the committee's view, this sampling and analysis applied only to homogeneous waste is unnecessary: If acceptable knowledge documentation…provides sufficient characterization information for heterogeneous waste, the committee can identify no technical reason why acceptable knowledge should not also be adequate for homogeneous waste.

The proposed alternative is a reduction or elimination of homogeneous waste sampling and analysis to confirm AK.

5.9.2.1 Assessment of risks, costs, and other impacts

According to the HWFP, the risks addressed by this characterization activity are related to the potential toxic characteristics of homogeneous waste due to the presence of metals or other hazardous compounds. Risk information is needed to determine the health and safety consequences to humans or the environment related to the sampling and analyses of homogeneous waste. Details on the efforts and costs of performing homogeneous solids sampling and analysis are in Chapter 4. Characterization data produced involve measuring the concentration of 30 VOCs, 11 semi-VOCs, and 14 metals. Other hazardous components may be added to the characterization data requirements for a waste stream if they are found in more than 25 percent of the sample for a given waste stream. To the best of the committee's knowledge, the information acquired through this characterization activity is not used to make any decision on handling, transportation, or disposal of CH-TRU wastes.

Table 4.1 shows that this is the most expensive characterization activity (on average) because of the need to prevent contamination of workers and of the workplace during sampling (drilling into the solid waste) and analyses. These waste characterization activities require from 8 to 40 person-hours and cost an average of $87,000 for each unit on which they are performed. That averages to $430 per waste container for the sampling and analysis over all units characterized.

A change in this characterization activity would require a HWFP modification. Previous modifications to this requirement have already been approved by NMED (see Section 3.3). These changes concern statistical quality control methods, quality control requirements for two semi-VOC analytes, and the reduction from three to one sample from each core (EEG, 2003b). A societal impact of a change to this characterization activity has a potential to decrease of public confidence in DOE particularly if an accident occurs during handling, transportation, or disposal of uncharacterized homogeneous waste.

5.9.2.2 Cost-effectiveness analysis

It appears that the information gathered with homogeneous waste sampling and analysis has low or no value. In that case, reducing or eliminating this activity could reduce costs without affecting the protection of human health and safety and the environment. The New Mexico Environmental Evaluation Group independently reached the same conclusion and wrote (EEG, 2003b; page 60):

> The EEG continues to believe that the homogeneous sampling and analysis are unnecessary waste characterization requirements in the HWFP. Our principal reason for this position is that the data are not used

> for any additional regulatory control (metals releases from accidents or long-term processes would be controlled by radionuclide control requirements and VOCs and semi-VOCs by [headspace gas sampling and analysis] or the Confirmatory VOC Monitoring Plan).

To decide whether a permit modification would improve the program, the advantages of performing less or no homogeneous waste sampling and analysis are to be considered along with the time and effort to prepare a permit modification request to NMED, as well as with the risks of decreasing the confidence of the public in New Mexico and that of corridor states in the safety of WIPP operations.

5.9.3 Visual examination to confirm radiography results

Visual examination as a quality control check on radiography results on existing waste (or retrievably stored waste, according to DOE's terminology) is the second most expensive activity per unit container. A previous National Research Council committee wrote (NRC, 2001; page 80):

> there is no requirement[10] for verification of real-time radiography results…. The visual examination confirmation is a self-imposed procedure that yields no benefit but results in increased risk of exposure and cost.

The proposed alternative is to decrease the size of the statistical sample or to eliminate this activity completely to reduce waste handling.

5.9.3.1 Assessment of risks, costs, and other factors

Visual examination provides information designed to assess risks related to the hazard of mis-certification, that is the risk of handling and disposing waste that is not suitable for transportation to and disposal at WIPP or estimating an erroneous waiting time to comply with the drum age criterion. Experience gathered to date could provide statistics on how often and which items were mis-identified using radiography, how often visual examination has produced new information, or what is the test-retest or inter-operator reliability of radiography operators. Risk information is needed on the impact on human health and safety of mis-certification, miscalculating a drum age criterion or material parameters weights. Information is also needed on worker exposure during this activity to compare benefits and risks of performing this characterization activity.

Details on the efforts and costs to perform statistical visual examination to confirm real-time radiography results for existing (or retrievably stored, in DOE's terminology) waste are in Chapter 4. The information gathered through this activity is used to determine the mis-certification rate and to verify the aging calculated by radiography (the latter is done by visually examining the packaging configuration, type and number of filters, and inner layers of confinement). Operational decisions (i.e., whether to ship the waste or to open containers found within the waste) are also made on the basis of visual examination information.

A change in this activity would require a HWFP modification. As previously noted, DOE has already obtained some relief from this requirement from NMED (see Section 3.3.2). The societal impact of a change to this requirement could be a decrease of public

[10]The committee referred to requirements in the Land Withdrawal Act, RCRA, Titles 40 CFR 191, 40 CFR 194, or 40 CFR 264. Visual examination is now a regulatory requirement because it has been included in the HWFP.

confidence in DOE particularly in case of an accident due to an overlooked item that visual examination and segregation work could have eliminated.

5.9.3.2 Cost-effectiveness analysis

Real-time radiography is generally an efficient and effective characterization activity. Operators are trained to recognize prohibited items, although they cannot read labels or estimate weights through radiography. This is done by opening the drums and physically handling objects. Radiography is already a confirmation technique for AK; visual examination is now a second type of confirmation. Given the high costs of this activity, the potential for worker exposure, the existence of redundancies in the characterization process to ensure that only waste complying with Waste Acceptance Criteria is shipped to WIPP and the (apparently) marginal benefits of checking relatively accurate radiography results on a small percentage of containers, it appears that visual examination to confirm radiography results on existing waste has low value.

Concerning this characterization activity, the New Mexico Environmental Evaluation Group writes (EEG, 2003b; page 59):

> The [visual examination] process has the potential for slightly greater radiation exposure than the other waste characterization requirements, although the EEG has not been provided any data from the DOE to indicate that exposures are significant enough to justify reducing the requirement. The DOE has been successful in modifying the HWFP on retrievably stored visual examination and this would be the preferred process for seeking further reductions.

To decide whether a permit modification would improve the program, additional risk information is needed along with an analysis of the policy and societal impacts of a change to this characterization activity.

6

Findings and Recommendations

This chapter contains the committee's findings and recommendations on the current contact-handled transuranic (CH-TRU) waste characterization program. As previously noted, U.S. Department of Energy (DOE) is responsible for making the policy decision to seek regulatory approval for changes to a particular characterization activity. In Finding and Recommendation 1, the committee recommends steps that DOE can take to assess the value of characterization activities based on a structured and quantitative analysis and given the experience gained from four years of operations at the Waste Isolation Pilot Plant (WIPP). Findings and Recommendations 2 through 6 concern operational changes based on the experience gathered thus far and on policy and societal impacts of changes to the characterization program.

6.1 OBSERVATIONS

Bringing WIPP to operational status is a significant achievement, given the technical and societal challenges of operating the first and only deep geologic repository for transuranic waste and the complex regulatory environment under which WIPP operates[1] (see Chapter 3). Stored CH-TRU waste is now being moved out of surface facilities at the DOE sites, characterized according to a CH-TRU waste characterization program negotiated between DOE and WIPP's regulatory agencies, and shipped to and disposed at WIPP.

During the development of the facility, WIPP has followed a regulatory path typical of many first-of-a-kind facilities with non-routine permits. While drafting the transuranic waste characterization program, DOE proposed characterization activities on the basis of a conservative interpretation of regulatory requirements.[2] The U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED), the regulators overseeing WIPP, reviewed and approved the inclusion of these activities in WIPP's proposed characterization program.

Four years after beginning of WIPP operations, DOE's waste characterization program has become controversial because some—including DOE, the New Mexico Environmental Evaluation Group and previous National Research Council committees— have suggested that some of the characterization activities are too extensive, costs are too high, and some of the information gathered is not used to make any decision related to the protection of human health and safety or the environment. On the other hand, stakeholders in New Mexico have argued that all the current characterization activities are necessary to ensure an adequate level of protection.

[1]One of the major regulatory challenges is to demonstrate that radioactive releases from WIPP will be lower than regulatory limits for 10,000 years.

[2]That is, DOE introduced rigorous measures in its waste characterization program, including 100 percent sampling, redundant testing, and extensive confirmation of existing data for the purpose of compensating for the absence of experience in handling this aged waste. Such an approach is favored by regulators in general.

The initial application of conservative requirements is not uncommon for a first-of-a-kind regulated facility, in part because regulators and permittees have no direct operational experience on which to base decisions (see Sidebar 3.2). As operational experience and analysis lead to better understanding, some activities could be modified, reduced, or eliminated and others added. Characterization activities may be added if, for example, a systematic analysis of risks along with operational experience show that there is a specific waste characteristic having a large impact on the protection of human health and the environment that is currently not well characterized either through measurements or Acceptable Knowledge (AK) in certain waste streams. Using the same approach, characterization activities could be reduced or eliminated.

Before such changes can be made, the permittee must demonstrate to the regulator that the proposed changes can provide the required level of safety and meet regulatory requirements. As discussed in Section 3.3 and Sidebar 3.2, the permitting process for WIPP (namely the EPA and the U.S. Nuclear Regulatory Commission [UNRC] Certificates of Compliance and the NMED Hazardous Waste Facility Permit [HWFP]) is following this approach. DOE has submitted requests to modify its characterization program to NMED, USNRC, and EPA, the majority of which have been approved (see Section 3.3).

As with any unique and complex endeavor, there are opportunities for improvement in the waste characterization program as operational experience is gathered. Below, the committee recommends steps that DOE can take to identify and support such improvements based on the experience gained from four years of operations.

6.2 FINDINGS AND RECOMMENDATIONS

Findings and recommendations are based on the analyses in previous chapters, information gathered at committee meetings, a site tour at the Savannah River Site, and other materials submitted to the committee during this study.

Finding 1: DOE has stated that some characterization activities are too expensive and time consuming and can be modified without increasing risks while reducing characterization time and costs. However, DOE has not presented a systematic analysis to support this argument to the committee, the regulators, or to the public. Although DOE has performed analyses of many aspects of operations related to WIPP performance, including transportation, the committee could find no studies that explicitly, systematically, and quantitatively link its waste characterization program to risks to the public, workers, or the environment.

Recommendation 1: DOE should use a systematic and quantitative approach to determine the value of the information currently obtained by its waste characterization activities and the impact of possible changes to them. This approach should also be used to support permit modification requests and to communicate with the public. The approach should include analyses of the following types:

- an assessment of the risks of CH-TRU handling, transportation and disposal activities, including the current characterization activities; and
- an assessment of the impacts—risks, costs, and other impacts, including policy and societal impacts—of changes to the current waste characterization activities.

There are several approaches to achieve this goal. One example is a structured and quantitative analysis based on the value of characterization information collected. In the context of this report, the value of characterization information is determined by how much the information contributes to waste handling, transportation, or disposal decisions. If the information is used to make decisions about waste handling, transportation, or disposal, then it has an impact on the outcome of these decisions (for instance, on reducing risks, uncertainties, costs, or delays), and thus it has value. **On the other hand, if the characterization information is not used in current or future decisions, then it has no impact, and therefore it has no value** (see Chapter 5). DOE should use such an analytical approach to identify the connections between waste characterization, risks, and costs, and to determine which activities impact these connections. If weak connections are found, the same structured and quantitative approach should be used to develop a rationale to request changes from the regulators. This analysis should be published so that outside parties can evaluate the present characterization program and the rationale for proposed changes to the program.

The proposed structured and qualitative analysis of alternative approaches are useful tools for evaluating changes to the characterization program but DOE should also recognize other factors, such as potential delays in permit modifications requests, time and costs to train and implement different procedures at the generator sites, uncertainties in characterization needs for future waste streams, and potential for changes to undermine public confidence.

Rationale: In the documents that DOE submitted to the regulators to obtain a permit and certifications to begin operations at the WIPP facility (see Section 5.3), the committee has not found any link of waste properties to system safety and performance. A risk-based quantitative analysis is necessary to demonstrate to the regulators and the public that proposed changes in characterization activities do not increase the risks to the public, workers, or the environment. In addition, an analysis of the value of the resulting information is useful to ensure that the proposed changes are cost-effective.

Such an analysis should start with a baseline assessment of the risks to the public, workers, and the environment using the current characterization activities. Since the characterization activities are intended to be protective, one would expect that this baseline analysis would reveal low or insignificant risks. To justify and support changes in the characterization program, DOE will have to conduct an analysis of the impacts of these changes on risk, costs, and operations. In addition, the proposed changes need to be supported by a cost-effectiveness analysis.

In Chapter 5 the committee provides applications (albeit incomplete) of a structured and quantitative approach to three characterization activities: 1) headspace gas sampling and analysis; 2) homogeneous solids sampling and analysis; and 3) visual examination to confirm radiography results for existing waste. These characterization activities appear to be good candidates for the structured and quantitative analysis proposed by the committee (Section 5.9). Such an analysis could help DOE evaluate the possibility of changing the requirements for headspace gas sampling from 100 percent to a statistically determined, representative sample of drums. If no unacceptable concentrations of prohibited gases are found during future operations, it could be possible to progressively reduce the size of statistically determined samples. There may also be more cost-effective ways to gather the information, such as measuring volatile organic compounds concentrations in WIPP's disposal panels. Similarly, the requirement for homogeneous solids sampling and analyses could be examined to see the extent to which it is necessary to core all homogeneous waste drums. The need for visual examination, which involves opening the drums and handling the waste, to confirm radiography results for existing waste, could be also be evaluated through the proposed analytical framework to reduce any potentially unnecessary worker exposure and potentially save time and money.

Finding and Recommendation 1 refer to the value of specific activities that constitute the characterization program. In addition, the committee presents five other findings and recommendations that are operational in nature, that do not address specific characterization activities, some of which may be instituted without regulatory approval.

Finding 2: DOE now has four years of operational experience with the National Transuranic Waste Management Program that can be used to improve the waste characterization activities. Examples of uses of operational experience are described in Section 4.6.

Recommendation 2: DOE should use its increasing experience base and advances in technology to improve the current TRU waste characterization program.

Rationale: With four years of operation and 40,000 drum-equivalents disposed in WIPP, DOE has acquired and continues to acquire significant knowledge and operating experience in waste characterization. The information gained from operational experience could be helpful in the analysis of the waste characterization program. Using the experience gathered to date, DOE could identify instances in which statistical methods (rather than confirmation of 100 percent of AK) would be adequate to provide information on the waste that would be protective of the health and safety of humans and of the environment.

The following are examples of potential improvement opportunities together with uses of information from an expanding operational experience base acquired thus far (see Section 4.6.1):

- Experience can be used to estimate the extent to which each characterization activity provides information that is: 1) essential to protect health and safety, 2) redundant with other activities or with historical knowledge of the waste, and 3) used to make decisions about waste handling, transportation, or disposal at WIPP. This information is to be used in the structured and quantitative analysis of the characterization program described in Chapter 5.
- Analysis of the characterization data acquired to date along with continuing characterization of increasingly diverse waste streams could identify new opportunities to use statistical sampling (rather than 100 percent of the waste stream) or different methods to confirm AK to provide information that would be as protective of health and the environment as the current measurements (see Sections 4.6.2 and 4.6.3).
- Experience provides a basis for "know-how" transfer from one generator site to others. The application and sharing of improvements in management methods acquired at generator sites thus far can achieve cost, schedule, and worker dose reduction across the DOE weapons complex (see Section 4.6.1).
- Experience allows a better understanding of costs and their variability across the waste inventory and generator sites as well as a better understanding of the relative value of different characterization methods providing similar information (i.e., radiography versus visual examination). Understanding why characterization costs differ significantly from waste stream to waste stream and

from site to site could also lead to better cost estimates for future waste streams (see Chapter 5). Changes to the characterization program that would improve the characterization process, together with an expanding operational experience base, could help reduce both risks and costs. However, if new and more difficult or complex waste types have to be dealt with in the future, or more stringent cleanup standards are imposed by the regulators, then characterization costs could go up (see Section 5.4).

Finding 3: Current characterization activities are applied generically to all waste types and, with few exceptions, are not tailored to particular waste streams.

Recommendation 3: DOE should propose to its regulators a more flexible waste characterization program that can take into account the properties of different waste streams, allowing more efficient and effective waste characterization operations.

Rationale: There are categories and subcategories of TRU waste that may require different methods of characterization depending on whether they are existing wastes, wastes that pose special problems (see Sections 2.3 and 2.4), or to-be-generated wastes. Opportunities exist to materially reduce the time, cost, and potential for risk to workers, the public, and the environment by recognizing that CH-TRU wastes are generated in many different ways, with many different characteristics, properties and compositions. The rationale for this finding is twofold: first, some CH-TRU waste streams, by the nature of their generation, their physical and chemical properties, and other special circumstances can be shown not to require the entire suite of characterization activities that are currently being carried out. For example, as noted in Chapter 4, DOE has already obtained an exemption to headspace gas analysis for thermally treated waste at Rocky Flats Environmental Technology Site. Second, current characterization methods or technologies are unsuitable for certain waste streams.

Wastes generated in the future (to-be-generated waste) may be better characterized than existing waste, as a result of improvements in management methods, processes, and record keeping. Therefore, some to-be-generated waste may not require any, or as much, confirmation of the information collected at the time of waste generation. Recognizing the differences among waste streams and capitalizing on the opportunities that the improved waste characterization information affords, DOE could propose to its regulators reducing or eliminating some of the current characterization activities for certain waste streams provided it supports its case with a systematic, analytical, and quantitative approach (see Recommendation 1). In addition, DOE should begin detailed planning to address the technical challenges presented by certain waste streams that it has not handled to date, as described in Sections 2.3 and 2.4.

Finding 4: DOE is currently using only one of the four methods approved by EPA in 40 CFR 194.22(b) to qualify information as Acceptable Knowledge (AK), namely, confirmation by measurement. Use of the other methods as appropriate could potentially reduce waste handling and costs, increase the efficiency of characterization activities, and extend the use of AK for waste to be generated in the future.

Recommendation 4: DOE should request authorization from its regulators to use all four methods allowed by EPA in 40 CFR 194.22(b) for qualifying waste information to be used as AK.

Rationale: In 40 CFR 194.22(b), EPA set forth four methods that can be used to qualify information to be used as Acceptable Knowledge of the waste, if an approved quality assurance program was not in place when the information was acquired. The methods are:

1. peer review,
2. use of corroborative evidence,
3. confirmation by measurement, and
4. qualification of a different quality assurance program.

DOE currently relies on confirmation by measurement and, in most instances, interprets this to require characterization of waste in every container. Although existing CH-TRU waste was generated, stored, and packaged under a wide variety of processes and conditions, it may be possible to use one of the other three methods to qualify AK for specific waste streams. For instance, under certain circumstances, it may be possible to qualify the quality assurance program used for safeguards purposes, which produces information on plutonium, americium, and uranium-235. This could reduce worker exposure and costs by reducing the handling and opening of waste drums in order to conduct tests. As generator sites incorporate DOE's waste characterization program in their waste generation processes and bring them under their quality assurance programs, it is desirable to take advantage of these actions to qualify the AK for these waste streams.

In the case of waste to be generated in the future, DOE has an opportunity to establish an approved quality assurance program in advance of generating the waste and to reduce its reliance on confirmation by measurement. As with all the changes in the characterization program, any change to the methods used to qualify existing information about the waste should follow the established regulatory process for making such changes. The challenging waste streams that DOE will have to characterize in the future may result in increased risk and technical challenges during confirmation of AK; thus, the use of other methods may become more suitable than confirmation by measurement for lowering risk and increasing efficiency.

As experience is gained with techniques such as radiography, improvements in how they are used may provide a basis for changes in confirmation techniques, at least for some types of waste. To adopt the newer technologies, DOE will be required to apply for a modification to the current characterization program. The lack of flexibility may slow the use of new or improved characterization methods. The current program does not have the flexibility to take full advantage of this type of improvement of the characterization process.

Finding 5: Transportation agreements for WIPP shipments have been fashioned over many years of negotiation between DOE and the corridor states. Any changes in the WIPP characterization program could be viewed as undermining these institutional agreements.

Recommendation 5: In addition to working with its regulators, DOE should ensure that corridor states are kept informed of negotiations for changes to the characterization program. Specifically, DOE should communicate effectively with the Western Governors Association, the Southern States Energy Board, and similar groups representing corridor states. DOE should analyze, publish, and present to corridor states' representatives any impact of proposed changes on transportation safety.

Rationale: Significant and protracted effort has been expended to demonstrate to the transportation corridor states that TRU shipments can be transported safely to WIPP under the Western Governors Association transport protocols (see Sidebar 3.1 for a discussion of the Western Governors Association). Corridor states and the Western Governors agreements and the transport protocols are founded on the expectation that TRU wastes are characterized in full accordance with EPA, NMED, and transportation regulations. Any change in the characterization program proposed by DOE, even if not directly related to transportation, could raise concerns on the part of corridor states that the underlying foundation of the WGA protocols may be compromised. It is the committee's view that a structured and quantitative approach used in discussions among DOE and corridor states could be useful for addressing both the technical and non-technical concerns.

Finding 6: Stakeholders have many concerns about WIPP program-related operations. Although specific concerns may vary among people who live near generator sites (risks to site workers, delay in removing waste from generator sites), along transportation corridors (the adequacy and reliability of characterization in the event of a transportation accident), or near the WIPP facility (protection of public health over the long term), some concerns are generally shared (the quality of DOE's requests for permit modifications; risks to workers, the public, and the environment; and the adverse effects of external performance pressures on the safety of the cleanup program). Many people who provided comments to the committee expressed concern that any change in characterization requirements or activities could result in decreased protection of worker and public health and/or the environment.

Recommendation 6: DOE should publish clearly written analyses of proposed changes to the characterization program to document that these changes do not adversely affect the protection of worker and of the public health and/or of the environment. DOE should also provide public access to information about WIPP and its operations, including the WIPP Waste Information System,[3] and communicate interactively with state officials, tribes, public interest groups, scientific oversight organizations, and concerned citizens. In this context, the proposed analytical framework could provide a technically defensible approach for supporting changes to the characterization program.

Rationale: State officials, tribes, public interest groups, and concerned citizens remain interested and engaged in issues about WIPP that may affect them. Among the concerns that the committee heard most often were the lack of access to information about ongoing characterization and waste emplacement activities and the quality of the analyses accompanying DOE's requests for changes to its characterization program. DOE could enhance confidence in and improve the clarity of its analyses, as well as its credibility, through open, well-reasoned discussions of the issues with interested parties, many of whom are well informed and have valuable historical information to contribute about the development of WIPP characterization activities and other issues. Transparency can be achieved by making characterization data available to the public in various forms, including published reports or accessibility to the WIPP Waste Information System or summary data. Characterization data would also provide a legal record of worker and public exposure should any future concern arise regarding the impact of these exposures on public health. The quarterly meetings between DOE, NMED, the New Mexico Environmental Evaluation Group, the New Mexico Office of the Attorney

[3]See the Glossary.

General, and interested members of the public are an example of the effort on the part of DOE to maintain communications and address concerns. The public will stay engaged. It is in the best interest of DOE to make that engagement as productive as possible.

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A

Biographical Sketches of Committee Members

Susan Wiltshire, *Chair,* is vice president emeritus of the consulting firm JK Research Associates, Inc. She has consulted with private and government agency clients in the areas of radioactive waste management, public involvement in policy and technical decisions, and risk communication, and has written and spoken extensively on those topics. Ms. Wiltshire has planned and facilitated public involvement projects, moderated multiparty discussions, and assisted with peer reviews of technical documents. She has served on a number of committees of the National Academies' National Research Council. Ms. Wiltshire has chaired the U.S. Environmental Protection Agency committee on the Waste Isolation Pilot Plant and served on the Secretary of Energy Advisory Board (1990 to 1994). She is currently a member of the board, and a scientific vice president of the National Council on Radiation Protection and Measurements, and chairs its Advisory Committee on Public Policy and Communication. Ms. Wiltshire authored the 1993 revision of the League of Women Voters' *Nuclear Waste Primer: A Handbook for Citizens.* She graduated Phi Beta Kappa with High Honors from the University of Florida, receiving a B.S. in mathematics.

Chris G.Whipple, *Vice-Chair,* is a principal of ENVIRON International Corp. in its Emeryville, California office. Environ provides consulting services mainly to private industry. He was elected to the National Academy of Engineering in 2001 for developing innovative risk assessment methodologies and for their application to issues of national importance. Dr. Whipple has consulted widely in the fields of radioactive waste management, and environmental risk assessment and management for private clients and government agencies. Prior to joining Environ, he worked at ICF Kaiser Engineers (1990–2000) and the Electric Power Research Institute (1974–90). He served on the National Academies' Board on Radioactive Waste Management (BRWM) from 1985 to 1995 and served as its chair from 1992 to March 1995. Dr. Whipple also served as a member of the BRWM Committee on the Waste Isolation Pilot Plant from 1989 to 1997. He holds a B.S. degree from Purdue University and a Ph.D. degree in engineering science from the California Institute of Technology.

John C.Allen is vice president of transportation practice at Battelle Memorial Institute. He has served in several positions at Battelle Memorial Institute including vice president for business development; transportation division manager of the Cambridge operations; manager in the Operations Research and Analysis Program and the Institutional and Policy Analysis Program; and transportation economist. Prior to joining Battelle in 1983, he was a transportation economist and policy analyst with the U.S. Department of Transportation. Mr. Allen has managed and participated in numerous studies relating to hazardous materials transportation. He has served on various advisory panels and was recently appointed chairman of the National Academies' Transportation Research Board's Committee on Hazardous Materials Transportation. He holds a B.A. in economics from Western Maryland College and an M.B.A. in transportation from the University of Oregon.

Ann Bostrom is an associate professor in the School of Public Policy at the Georgia Institute of Technology. Her areas of research interest are risk perception, communication, and management and the cognitive aspects of survey methodology. Her research on mental models of hazardous processes (how people understand and make decisions about risks) has been funded by the National Science Foundation, the National Institutes of Health, and the U.S. Environmental Protection Agency. Dr. Bostrom was awarded a Fulbright scholarship and the Lois Roth endowment award to study at Stockholm University. In 1997, Dr. Bostrom was awarded the Chauncey Starr Award for a young risk analyst from the Society for Risk Analysis. She holds a B.A. in English from the University of Washington, an M.B.A. from Western Washington University, and a Ph.D. in public policy analysis from Carnegie Mellon University.

Gregory R.Choppin is the R.O.Lawton Distinguished Professor of Chemistry at Florida State University. His research interests involve the chemistry and the separation science of the f-elements, and the physical chemistry of concentrated electrolyte solutions. During a postdoctoral period at the Lawrence Radiation Laboratory, University of California, Berkeley, he participated in the discovery of mendelevium, element 101. His research and educational activities have been recognized by the American Chemical Society's Award in Nuclear Chemistry, the Southern Chemist Award of the American Chemical Society, the Manufacturing Chemist Award in Chemical Education, the Chemical Pioneer Award of the American Institute of Chemistry, a Presidential Citation Award of the American Nuclear Society, and honorary D.Sc. degrees from Loyola University and the Chalmers University of Technology (Sweden). Dr. Choppin currently serves as a member of the National Academies' Board on Radioactive Waste Management. Dr. Choppin received a B.S. degree in chemistry from Loyola University, New Orleans, and a Ph.D. degree from the University of Texas, Austin.

Alfred Grella is an independent nuclear and hazardous materials transportation consultant. Mr. Grella retired in 1990 after a 40-year career that included 11 years in the nuclear industry followed by 27 years of U.S. government service at the Atomic Energy Commission, the U.S. Department of Transportation, and the U.S. Nuclear Regulatory Commission. During his distinguished career, Mr. Grella has worked as a professional in health physics, health protection, transportation, inspection and enforcement, training, and related regulatory activities. He has authored more than 30 published papers. Between 1970 and 1979 he served as the U.S. competent national authority at the U.S. Department of Transportation with respect to the International Atomic Energy Agency Regulations for Safe Transport of Radioactive Material. He is a member of the American Nuclear Society, a certified health physicist, and a fellow of the Health Physics Society. Mr. Grella received the M.Sacid (Sarge) Ozker Award from the American Society of Mechanical Engineers Radwaste Systems Committee in 1996 for distinguished service and eminent achievement in the field of radioactive waste management. Mr. Grella received a B.S. degree in chemistry from the University of Connecticut, followed by two years in the U.S. Air Force. In 1979, as the U.S. Department of Transportation's representative, he completed the one-year management program at the National Defense University Industrial College of the Armed Forces.

Michael Mobley is a private consultant on regulatory radiation-related issues. He is a retired director of the Tennessee Division on Radiological Health and worked in every aspect of the division's Radiation Control Program. He has represented the State of Tennessee since 1984 as a commissioner for the Southeast Low-Level Radioactive Waste Management Compact Commission. Mr. Mobley is a past chairperson of the Conference of Radiation Control Program Directors, Inc. (CRCPD), has served as that organization's treasurer, and has served on numerous committees and working groups for the CRCPD. He served on the Federal Facilities Committee, which has been charged by the CRCPD with developing and coordinating information regarding federal facility radiological impact issues. Mr. Mobley received the Gerald S.Parker Award in 1996 for his significant contributions to radiation protection and the CRCPD. In 2000 he was awarded Life Member status of the CRCPD (One of four awarded in 35 years). Mr. Mobley has also served as the state liaison officer for Tennessee to the U.S. Nuclear Regulatory Commission. Mr. Mobley received a B.A. degree in physics and mathematics from Austin Peay State University, an M.S. degree in physics from the University of Tennessee, and a master's degree in public administration from Tennessee State University. He is also a graduate of the Tennessee Government Executive Institute.

Kenneth L.Mossman is a professor of health physics and director of the Office of Radiation Safety at Arizona State University in Tempe, where he has also served as assistant vice president for research. Prior to his arrival at Arizona State University, Dr. Mossman was a faculty member of the medical and dental schools at Georgetown University in Washington, D.C., and was professor and founding chairman of the Department of Radiation Science at Georgetown's Graduate School. His research interests include radiological health and safety and public policy. Dr. Mossman has authored more than 150 publications related to radiation health issues. In 2003 he was awarded a John Simon Guggenheim Memorial Foundation Fellowship to study risk dimensions and precaution. Dr. Mossman served as president of the Health Physics Society and received its prestigious Elda Anderson Award, the Marie Curie Gold Medal, and the Founder's Award. He has been a Sigma Xi distinguished lecturer and a fellow of the Health Physics Society and the American Association for the Advancement of Science; he has served on committees for the National Research Council, the National Institutes of Health, the U.S. Nuclear Regulatory Commission, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (Paris), and the International Atomic Energy Agency (Vienna). Dr. Mossman earned a B.S. in biology from Wayne State University, M.S. and Ph.D. degrees in radiation biology from the University of Tennessee, and an M.Ed. degree in higher education administration from the University of Maryland.

Robert H.Neill served as director of New Mexico's Environmental Evaluation Group (EEG) from its creation in 1978 until his retirement in May 2000. The EEG performs an independent evaluation of the potential public health and environmental impacts of the Waste Isolation Pilot Plant (WIPP) in New Mexico. Mr. Neill directed a staff of scientists and engineers in the review and evaluation of work performed by the U.S. Department of Energy and its contractors at WIPP and in independent research and analyses on the radiation exposure of people. Upon his retirement from EEG, the Regents of New Mexico Institute of Mining and Technology, administrator for EEG, appointed Mr. Neill director emeritus. Prior to his work at EEG, Mr. Neill served as a commissioned officer in the Bureau of Radiological Health of the U.S. Public Health Service for 23 years. He has served on advisory committees to the National Academies, the U.S. Environmental Protection Agency, the U.S. Department of Energy, the Office of Technology Assessment, the World Health Organization, the International Atomic Energy Agency, the Aspen Institute, and the State of Tennessee. Mr. Neill received the degree of

Mechanical Engineer from the Stevens Institute of Technology and an M.S. in radiation hygiene from the Harvard University School of Public Health.

John Plodinec is director of the Diagnostic Instrumentation and Analysis Laboratory at Mississippi State University. His laboratory specializes in developing instrumentation for unusual environments and in characterizing processes and technologies under real-world conditions. Dr. Plodinec is an internationally recognized expert in waste management and glass science. He has made important contributions in several areas of radioactive waste management, ranging from waste characterization to glass durability modeling. Prior to joining Mississippi State University, he worked for 22 years at the U.S. Department of Energy's Savannah River Site, where he collaborated in building and operating the first remote in-cell melter and served as primary technical lead for the product qualification program. In that capacity he oversaw the remote-handled transuranic waste streams produced by the Savannah River Site. He has authored more than 90 publications, primarily on waste vitrification and the thermodynamics of waste management. He holds a patent on a device to sample high-level waste and a patent on a slurry-feeding device for glass melters. Dr. Plodinec earned his Ph.D. in physical chemistry from the University of Florida.

Detlof von Winterfeldt is the deputy dean of the School of Policy, Planning, and Development at the University of Southern California, and a professor of public policy and management. His research interests are in the foundation and practice of decision and risk analysis as applied to technology and environmental management problems. He is the coauthor of two books and more than 100 articles and reports on these topics. In 2000, the Decision Analysis Society awarded Dr. von Winterfeldt the Ramsey Medal for distinguished contributions to decision analysis. He has served on several committees and panels of the National Science Foundation, including the Advisory Panel for the Decision and Risk Management Science Program, as well as on the National Academies' Committee on Risk Perception and Risk Communication. Dr. von Winterfeldt received M.A. and B.A. degrees in psychology from the University of Hamburg, Germany, and a Ph.D. in mathematical psychology from the University of Michigan.

Raymond G.Wymer is a consultant for the Oak Ridge National Laboratory, the U.S. Department of Energy, and its various contractors on all aspects of the nuclear fuel cycle and radioactive waste management. He has served on a United Nations Special Commission to Iraq and consulted with the U.S. Department of State on nuclear nonproliferation matters. He is a former director of the Chemical Technology Division of Oak Ridge National Laboratory. Dr. Wymer is a specialist in radiochemical separations technology for radioactive waste management, nuclear fuel reprocessing, and uranium isotope separation by chemical exchange. He serves as a member of the Advisory Committee on Nuclear Waste for the U.S. Nuclear Regulatory Commission. He is a fellow of the American Nuclear Society and the American Institute of Chemists. Dr. Wymer has been honored with the American Institute of Chemical Engineers' Robert E. Wilson Award in Nuclear Chemical Engineering and the American Nuclear Society's Special Award for Outstanding Work on the Nuclear Fuel Cycle. He received a B.A. from Memphis State University and an M.A. and Ph.D. from Vanderbilt University.

B

Information-Gathering Meetings

This appendix describes the committee's four information-gathering sessions throughout the study. Presentation titles and speaker names (in parentheses) are provided below. The committee held an additional meeting devoted to the writing of this report. All of the information received by the committee is publicly available.

B.1 FIRST MEETING: OCTOBER 28–29, 2002 (CARLSBAD, NEW MEXICO)

- Waste Isolation Pilot Plant (WIPP) Update. (R.Nelson, U.S. Department of Energy, Carlsbad Field Office)
- Contact-Handled Transuranic (CH-TRU) Waste Characterization (M.Doherty, U.S. Department of Energy-National TRU Program)
- Transportation of TRU Waste-Packaging, Characterization, and Shipping Limitations, Washington TRU Solutions (P.Gregory, Washington TRU Solutions)
- Opportunities for Improving Characterization Efficiencies (D.Moody, Los Alamos National Laboratory, Carlsbad Operations)
- New Mexico Environment Department (NMED) Permit Modification and U.S. Environmental Protection Agency (EPA) Change Notification, Three Years of Operating Experience at WIPP (B.Kehrman, Washington TRU Solutions)
- U.S. Environmental Protection Agency's WIPP Waste Characterization Requirements (B.Forinash, EPA, Office of Radiation and Indoor Air)
- New Mexico Environment Department's View on WIPP Contact-Handled waste (CH-TRU) Waste Characterization (S.Zappe, NMED and C.Walker, Trinity Engineering Associates)
- Establishing and Operating a Nuclear Waste Repository—The Role of the Environmental Evaluation Group's (EEG's) Independent Technical Oversight (M. Silva, Environmental Evaluation Group)
- EEG's Views on WIPP Characterization and Transportation Requirements (M. Silva, Environmental Evaluation Group)
- EEG'S Views on WIPP Characterization and Transportation Requirements (J. Channell, Environmental Evaluation Group)

B.2 SECOND MEETING: JANUARY 28, 2003 (SANTA FE, NEW MEXICO)

- Some Additional Comments on the Committee's December 6, 2002 Questionnaire (D.Hancock, Southwest Research and Information Center)
- Some Comments and Additional Questions for the National Research Council (NRC) Committee's December 6, 2002, Questionnaire About Transuranic Waste Characterization and Transportation Concerns (J.Arends, Concerned Citizens for Nuclear Safety and D.Reade, Citizens for Alternatives to Radioactive Dumping)
- EEG Response to the NRC WIPP Committee's December 16, 2002, Questionnaire (J.K.Channell, EEG)
- Shipping to WIPP versus Intersite: A Contrast of Characterization and Transportation Requirements (P.Gregory, Washington TRU Solutions)
- Transuranic Waste Characterization Cost Analysis (J.Powell, U.S. Department of Energy, Center for Acquisition and Business Excellence, National Energy Technology Laboratory)
- What's in WIPP? Four Years' Radioactive Waste Disposal, Three Year's Hazardous Waste Disposal (R.Nelson, U.S. Department of Energy, Carlsbad Field Office)
- Data Management Under the Provisions of EPA and NMED Requirements (P. Rogers, Los Alamos National Laboratory)
- Radiography at WIPP (M.Doherty, Technical Specialists, LLC)
- Nondestructive Assay of Transuranic Wastes (P.Kelly, S.Cohen and Associates)

B.3 THIRD MEETING: MARCH 3–5, 2003 (AUGUSTA, GEORGIA)

- Improvement in the Resource Conservation and Recovery Act (RCRA) Waste Characterization Program for WIPP (J.W.Porter, Waste Policy Center)
- Central Characterization Project (F.Sharif, Washington TRU Solutions)
- Savannah River Site TRU Waste Program (P.D.Hunt, Westinghouse Savannah River Site)
- Transuranic Waste Performance Management Plan (I.Triay, U.S. Department of Energy, Carlsbad Field Office)
- Cost of Characterization Status Report (J.Powell, U.S. Department of Energy, Center for Acquisition and Business Excellence, National Energy Technology Laboratory)

- Savannah River Site (SRS) Overview. Historical and Future Roles of SRS in the Nation's Nuclear Programs (R.Ford and H.Crapse, U.S. Department of Energy-SRS)
- Savannah River Site Citizens Advisory Board Perspective on SRS Transuranic Waste (W.Waters, SRS Citizens Advisory Board)

B.4 FOURTH MEETING: MAY 19, 2003 (WASHINGTON, D.C.)

- TRU Waste Characterization at the Rocky Flats Environmental Technology Site (J.O'Leary and M.Spears-Kaiser Hill)
- TRU Waste Characterization at the Advanced Mixed Waste Treatment Facility of the Idaho National Engineering and Environmental Laboratory (M.Wheeler-British Nuclear Fuel Limited).
- Cost of Characterization Final Report (J.Powell, U.S. Department of Energy, Center for Acquisition and Business Excellence, National Energy Technology Laboratory)
- Roundtable Discussion on TRU Waste Characterization (I.Triay, U.S. Department of Energy, Carlsbad Field Office; M.Silva, Environmental Evaluation Group; and D.Tiktinsky, U.S. Nuclear Regulatory Commission)

C

Characterization-Related Requirements in WIPP Regulatory Documents

Prior to shipping waste to the Waste Isolation Pilot Plant (WIPP), waste generator sites must characterize their waste streams and certify that they satisfy the WIPP Waste Acceptance Criteria (WAC). The applicable requirements of the WAC are traceable to several documents, including WIPP operational safety requirements derived from the WIPP Land Withdrawal Act, the U.S. Environmental Protection Agency (EPA) Compliance Certification Decision, the New Mexico Environment Department (NMED) Hazardous Waste Facility Permit (HWFP), and the transportation requirements for contact-handled transuranic (CH-TRU) waste derived from the Transuranic Packaging Transporter-Model II (TRUPACT-II) Certificate of Compliance. The characterization requirements in these documents are described in the following sections.

C.1 LAND WITHDRAWAL ACT REQUIREMENTS FOR TRANSURANIC WASTE IN WIPP

The Land Withdrawal Act, Public Law 102–579, is the guiding legislation for WIPP (U.S. Congress, 1992). In this Act, Congress established the scope and legal criteria for the facility, withdrew the land at the WIPP site from “entry, appropriation, and disposal,” and gave DOE control over the site. The Land Withdrawal Act also assigned EPA regulatory authority over radioactive waste standards and final disposal regulations. The Land Withdrawal Act includes many other requirements and provisions pertaining to the protection of public health and the environment.

The Land Withdrawal Act establishes the five principal legal requirements relevant to WIPP waste characterization:

1. *Nature of waste to be disposed in WIPP.* WIPP can receive only transuranic waste generated by atomic energy defense activities.
2. *Total volume of transuranic waste.* WIPP is allowed to contain up to 175,564 cubic meters of transuranic waste.
3. *Volume of remote-handled transuranic (RH-TRU) waste.* WIPP is allowed to contain up to 7,080 cubic meters of RH-TRU waste.
4. *Total activity of RH-TRU waste.* RH-TRU waste received at WIPP shall not exceed 23 curies per liter maximum activity level (averaged over the volume of the container). The total curies of RH-TRU waste received at WIPP shall not exceed 5.1 million.
5. *Surface dose rate.* No TRU waste received at WIPP may have a surface dose rate exceeding 1,000 rems per hour. No more than 5 percent by volume of RH-TRU waste received at WIPP (354 cubic meters) may have surface dose rates exceeding 100 rems per hour.

The Land Withdrawal Act charges the EPA with the responsibility for establishing a set of environmental, safety, and health requirements that must be met before waste acceptance and disposal. The Department of Energy (DOE) is responsible for showing EPA that the limits on the nature, volume, surface dose rate, and total activity of the waste emplaced in WIPP do not exceed those established in the Land Withdrawal Act.

The Land Withdrawal Act also established the New Mexico Environmental Evaluation Group (EEG) as an oversight organization for the WIPP project on behalf of the State of New Mexico. Although EEG has no regulatory authority, it has had an oversight role since its creation in 1978 to conduct an independent technical evaluation of WIPP and to ensure the protection of the public health and safety and the environment. EEG roles include the review and evaluation of all proposed standards, transportation information, audits of characterization procedures at the generating sites, and analyses of water, soil, and organic samples jointly obtained with WIPP environmental monitoring programs.

C.2 CHARACTERIZATION REQUIREMENTS IN THE EPA CERTIFICATION OF COMPLIANCE

The EPA's goals when establishing disposal standards are, among other things, to maintain acceptable risks to individuals, sources of drinking water, and the environment in the vicinity of radioactive waste disposal facilities. As required by the Land Withdrawal Act, EPA issued the final WIPP disposal standards titled "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Wastes" (40 CFR 191) in April 1993. In 1996, EPA promulgated the criteria for the certification and recertification of WIPP's compliance with 40 CFR 191 (40 CFR 194). In 1998, EPA declared WIPP to be in compliance with its disposal regulations and granted the facility a certification. WIPP must be recertified every five years. DOE is now working on the recertification application due in 2004.

The purpose of EPA's characterization requirements is to ensure that WIPP remains in compliance with the EPA certification criteria and limits set forth in the Land Withdrawal Act. As a basis for its certification decision, EPA used DOE estimates for TRU waste inventories and probabilities of features, events, and processes for the next 10,000 years to assess the long-term performance of WIPP. Therefore, DOE must ensure through waste characterization that the fundamental information and assumptions about the waste inventory remain consistent with waste parameters used in the certification, or it must reassess WIPP performance based on new information. DOE used a computer model, called the performance assessment, to evaluate the long-term performance of WIPP, as explained below.

C.2.1 WIPP's performance assessment

The WIPP performance assessment quantifies[1] the ability of a repository to satisfy the limits (published in 40 CFR 191, Appendix A) on the release of radionuclides from a repository over a period of 10,000 years. The performance assessment calculates, organizes, and presents information relevant to long-term repository behavior. This is accomplished, in part, by assessing the probabilities and consequences of major scenarios by which radionuclides can be released into the environment. Important scenarios include those involving human activities that might unintentionally[2] compromise the integrity of the repository. The performance assessment process consists of the following:

[1]Because of the inherent uncertainty in calculations of long-term effects, EPA also set assurance requirements to improve confidence. These requirements do not have to be quantified.

[2]EPA's regulations do not include consideration of doses to anyone who deliberately tries to breach the disposal system.

1. compiling features, events, and processes that could affect the disposal system (e.g., the waste forms);
2. classifying events and processes to enhance consistency and completeness;
3. screening individual events and processes for likelihood of occurrence and consequences;
4. combining events and processes into specific scenarios;
5. screening scenarios to identify and eliminate those that have little or no effect on the performance assessment;
6. modeling the scenarios;
7. calculating the releases; and
8. comparing the calculated values with the allowable releases.

EPA's regulations also require DOE to describe the sampling, measurement, and tracking methods necessary to quantify these components. In the Compliance Certification Application, DOE proposed—through the Waste Acceptance Criteria and other portions of the application—a comprehensive matrix of assay methods and sampling regimes that was accepted by EPA as the basis for the certification decision.

The performance assessment was calculated using the 10 radionuclides that comprise over 99 percent of the waste inventory, which are: americium-241, cesium-137 (and its daughter barium-137m), curium-344, plutonium-238, plutonium-239, plutonium-240, plutonium-241, strontium-90 (and its daughter yttrium-90), uranium-233, and uranium-234. Of these ten, strontium-90, uranium-233, and cesium-137 and their daughter products can be found in significant amounts only in RH- not CH-TRU waste streams. In the performance assessment, DOE also identified non-radiological waste parameters that could have an impact on the performance of the repository (Helton et al., 1998):

- *Amount of free water.* The EPA certification requirements include a limit on the total amount of water or brine present in the waste. This parameter is important both because the only significant pathway for release of radionuclides to the environment is through aqueous transport and because it controls several other factors, such as corrosion and gas generation.[3] The total limit for free water introduced in WIPP from waste is 1 percent by volume in the entire TRU waste inventory (175,564 cubic meters), which corresponds to 1,756 cubic meters. This limit derives from a transportation requirement forbidding shipment of hazardous waste containing more than 1 percent of free liquids by volume. DOE used this requirement as one of the initial assumptions in the performance assessment calculation, which was part of the compliance certification application. This free water requirement is now integrated as part of the EPA certification to ensure compliance with release limits. The 1 percent limit is not unique to WIPP. The U.S. Nuclear Regulatory Commission has a similar requirement for low-level waste (10 CFR 61).

[3]The main gases potentially generated in WIPP in the presence of brine are carbon dioxide, methane, and hydrogen. Oxygen is also generated (via radiolysis) but is assumed to be consumed by the metal. These gases are generated by microbial waste degradation inside WIPP. Hydrogen can also be produced by radiolysis or by corrosion of metal containers. An increase in gas pressure inside the repository could affect room closure rates, fracture development, brine inflow, and the possibility of waste entrainment in gas (called spalling) during an inadvertent drilling event. Such a drilling event could occur anytime after closure of the repository, when active institutional controls cease.

- *Amount of ferrous metals.* EPA certification requirements include a minimum amount of ferrous metals (20 million kilograms) to ensure a reducing environment inside the WIPP repository. A reducing environment maintains radionuclides with multiple valence states in the lower oxidation state, which usually corresponds to a lowered solubility.[4]
- *Amount of non-ferrous metals.* EPA Certification requirements include a minimum amount (2,000 kilograms) of nonferrous metals in WIPP. Many nonferrous metals such as calcium and magnesium form complexes with organic ligands present in waste (such as EDTA or citric acid).[5] This reduces the binding of actinides to these organic ligands, thereby reducing their solubility and consequently their mobility. Therefore, waste characterization is used to ensure that the amount of nonferrous metals in the waste is above the minimum required.[6]
- *Amount of biodegradable cellulosics, plastic, and rubber.* EPA certification requirements include a maximum amount (20 million kilograms) of cellulosics, plastic, and rubber in the waste to take into account the potential for gas generation from the decomposition of these organic materials. Therefore, waste characterization must ensure that the amount of cellulosics, plastic, and rubber in the waste is below the maximum.

Tolerable uncertainties or the level of accuracy of the characterization measurements have not been specified in the compliance certification application for the above limits. EPA writes in 40 CFR 194 (EPA, 1996, page 5227):

> The Agency does not expect or require that every drum of transuranic waste be opened in an effort to provide an exhaustive characterization of the contents. Rather, the Agency expects that DOE will sample drums of waste to the extent necessary and will combine the results with other information such as process knowledge to determine the waste characteristics. The level of accuracy needed in waste characterization is determined by the degree of accuracy assumed in the compliance application.

In summary, the purpose of WIPP waste characterization requirements in the EPA certification is to determine

1. activity and radiological inventory of the waste for the ten most abundant radionuclides;
2. nature of the waste and its container surface dose rate;
3. amount of metals (ferrous and nonferrous);
4. absence of free water above 1 percent by volume; and
5. amount of cellulosics, plastic, and rubber.

[4]This minimum will be met by the steel content of the drums in which the waste is to be shipped to WIPP.
[5]EDTA (ethylenediaminetetraacetic acid) and citric acid are common cleaning agents.
[6]This minimum limit has already been achieved at WIPP. Panel 1 alone contains over 50,000 kilograms of non-ferrous metals.

C.3 CHARACTERIZATION REQUIREMENTS IN THE NMED HAZARDOUS WASTE FACILITY PERMIT

EPA delegated to the state of New Mexico the regulation of the hazardous non-radioactive component of TRU waste under the Resource Conservation and Recovery Act (RCRA) (EPA, 1990). In 1999, the State of New Mexico granted WIPP a Hazardous Waste Facility Permit for the disposal of TRU mixed waste. The HWFP must be reviewed every 10 years. The NMED standards for a hazardous waste disposal facility (such as WIPP) seek to minimize releases[7] of nonradiological hazardous constituents during the operational phase and for a nominal 30-year period following repository closure.

The cornerstone of any hazardous waste permit under RCRA is the Waste Analysis Plan. Acceptance of the plan allows generators and disposal facilities to identify, treat, store, and properly dispose of hazardous wastes. The purpose of the HWFP's Waste Analysis Plan is to obtain a detailed chemical and physical analysis of a representative sample of the waste to provide all the information which must be known to store and dispose of waste at WIPP in accordance with RCRA. The requirements for TRU waste characterization used by NMED originate from the following standards for owners and operators of hazardous waste treatment, storage, and disposal facilities (40 CFR 264.13):

> (a)(1) Before an owner treats, stores, or disposes of any hazardous wastes, or nonhazardous wastes if applicable under §264.113(d), he must obtain a detailed chemical and physical analysis of a representative sample of the wastes. At a minimum, the analysis must contain all the information which must be known to treat, store, or dispose of the waste in accordance with this Part and Part 268 of this chapter.

Currently, the waste characterization requirements in the HWFP are aimed at determining the following information (HWFP, 2003):

1. physical form of the waste (homogeneous solids, soil or gravel, debris) and
2. exclusion from the waste of the following prohibited items:[8]

- liquid waste;
- nonradionuclide pyrophoric materials (addressed by the hazardous waste codes[9]);
- hazardous wastes that do not contain TRU waste;
- incompatible chemicals (addressed by the hazardous waste codes);
- explosives (addressed by the hazardous waste codes) and compressed gases;

[7] With an exemption from Land Disposal Restriction regulations (40 CFR 268), Congress determined that WIPP waste does not need treatment prior to disposal. As a result, the NMED imposed groundwater and air monitoring requirements to ensure that any detectable release of toxic materials remains below specific limits that have been established to protect human health and the environment.

[8] Additional prohibited items for WIPP are waste containers that do not have volatile organic compound concentrations reported for the headspace, waste containers that have not undergone radiographic or visual examination, and waste containers that do not have a certified waste stream profile form (see the Glossary).

[9] The definition of hazardous waste codes can be found in the Glossary.

- ignitable, corrosive, and reactive wastes (addressed by the hazardous waste codes); and
- remote-handled transuranic mixed waste.[10]

Prohibited items listed in the HWFP are items that are incompatible (e.g., ignitable when mixed or chemically reactive) or inappropriate for the WIPP facility. If combined, incompatible wastes are capable of spontaneous combustion, toxic gas generation, or explosions (EPA, 1994). Selection of waste characterization parameters must include measures to ensure that the waste is appropriate for WIPP's scope, and that inappropriate waste is identified and excluded prior to shipment. Therefore, incompatible, corrosives, and ignitable wastes are screened by prohibiting liquid waste in WIPP; reactive wastes are screened through hazardous waste codes. In summary, the NMED HWFP requires that DOE determine the physical form of the waste, its chemical constituents, and the absence of prohibited items.

As shown in Chapter 3, many of the characterization activities appearing in the HWFP were proposed by DOE to NMED before the opening of WIPP to facilitate the permit process (Section 3.3.2). DOE also obtained an exemption from the U.S. Congress (through a 1996 amendment to the Land Withdrawal Act) from the RCRA mixed waste requirements for treating hazardous waste.

C.4 REQUIREMENTS IN THE TRU WASTE AUTHORIZED METHODS OF PAYLOAD CONTROL

The U.S. Nuclear Regulatory Commission (USNRC) regulates the packaging of radioactive waste for transportation. Regulatory requirements are promulgated in 10 CFR 71. Each shipping container design destined for WIPP must obtain a USNRC Certificate of Compliance with the requirements in 10 CFR 71. To certify a package design, DOE must submit a Safety Analysis Report for transportation packages to the USNRC. This report describes the physical characteristics of the package, the quality assurance program for package design, and results of both normal testing conditions and incident or accident testing conditions. The USNRC issued Type B certification for TRUPACT-II in 1989. The requirements in the TRUPACT-II Certificate of Compliance are implemented in the CH-TRU Waste Authorized Methods of Payload Control (TRAMPAC). The TRAMPAC requirements are discussed in Appendix D. Briefly, the purpose of waste characterization requirements for waste transportation is to determine the following: container and physical properties, nuclear properties, chemical properties, gas generation, payload assembly requirements, absence of prohibited items, and adequate quality assurance practices.

The USNRC-authorized methods of compliance with characterization requirements are the following:

1. visual examination (e.g., remove prohibited items during waste generation);
2. visual inspection (e.g., verify filter model or drum integrity);
3. real-time radiography (e.g., verify absence of prohibited items);
4. records and database information (e.g., process knowledge to report absence of prohibited items for transportation);
5. administrative and procurement controls (e.g., procedures and/or purchase records could be a basis for reporting the absence of items prohibited for transportation);

[10]The current HWFP considers RH-TRU mixed waste a prohibited item because NMED has not yet approved a waste analysis plan for this type of waste (see Section 2.3).

6. sampling program (e.g., independent verification of 200 series stored waste); or
7. measurement (e.g., assay or drum weight).

C.5 REGULATORY BODIES

EPA and NMED are the only agencies with direct regulatory authority over waste disposal at WIPP, but a number of federal and state regulatory bodies are involved in WIPP activities, as shown in Table C.1. The complexity of the regulatory framework of WIPP in the context of the CH-TRU waste characterization program is discussed in Chapter 3.

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Table C.1 Agencies with Regulatory Responsibilities over the Disposal of Transuranic Waste at the Waste Isolation Pilot Plant

Agency	Responsibility	Authority	Purpose
EPA[a]	Regulates compliance with long-term radiological risks of disposal. Regulates radiation exposure of public at the land withdrawal boundaries.	Land Withdrawal Act (P.L. 102–579).	Prevention of latent cancer fatalities. Prevention of health effects to public beyond WIPP boundaries during operations. Protection of the environment.
NMED[b]	Regulates compliance with RCRA nonradiological constituents.	EPA has delegated authority over TRU mixed waste to the State of New Mexico.	Protection of public health and the environment.
USNRC[c]	Certifies radioactive material shipping containers.	Title 10 CFR 71.	Contain radioactive material in transportation packages.
DOE	Self-regulates worker and general public exposure to radiation and toxic chemicals according to regulations. Operates the TRANSCOM satellite communications and tracking system. Maintains the Radiological Assistance Plan and the radiological assistance team for planning and emergency response to transportation incidents or accidents. Participates in the Federal Radiological Preparedness Coordinating Committee under the Federal Emergency Management Agency.	Title 10 CFR 835, DOE 5400 Order Series.	Safe handling, emergency management, and disposal of radioactive waste generated during defense-related activities.
Department of Transportation (DOT)	Regulates the safe transportation of radioactive materials by providing planning and training grants to state, tribal, and local agencies to prepare for potential radioactive materials transportation incidents.	Hazardous materials Transportation Act of 1975, as amended by the Hazardous Materials Uniform Safety Act of 1990 (P.L. 101–615).	Ensures highway safety.

	DOT sets regulations covering radioactive materials labeling, placarding, and routing (49 CFR 173).	Title 49 CFR Parts 107 and 170–179.	
Corridor states regulatory authorities	Oversee truck inspections and emergency preparedness plans, participate in routes designation.	Agreements with DOE, New Mexico, and generator states.	Ensure safe and uneventful transportation of TRU waste.
Federal Emergency Management Agency	Regulates emergency preparedness plans.		
Mine Safety and Health Administration	Develops and enforces regulations to protect mine workers; makes recommendations to DOE concerning deficiencies cited during these inspections.		Ensure facility mining activities in accordance with best mining practices.
Occupational Safety and Health Administration	Develops and enforces regulations to protect workers' health and safety according to occupational standards.	Occupational Safety Health and Act of 1970.	Ensure occupational safety of workers at generator sites and WIPP as well as that of emergency responders.

[a]EPA has regulatory authority over the management and disposal of TRU waste through the WIPP compliance certification.

[b]NMED has regulatory authority over the management and disposal of the hazardous waste component of TRU mixed waste through the WIPP Hazardous Waste Facility Permit.

[c]USNRC has regulatory authority over shipping containers used to transport radioactive waste to WIPP through the shipping container's Certificate of Compliance.

D

Transportation Package Requirements Affecting Waste Characterization

This appendix provides some details on transportation requirements as they affect characterization activities for transuranic (TRU) waste. The 1992 Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act Section 16(a) (as amended) mandates that all waste destined for WIPP must be shipped in packages certified by the U.S. Nuclear Regulatory Commission (USNRC). The TRUPACT-II (Transuranic Packaging Transporter-II) and Half-PACT (a shorter version of the TRUPACT-II) are the transportation packages—a USNRC term for shipping containers[1]—currently authorized by the USNRC to ship contact-handled transuranic (CH-TRU) waste to WIPP.

To date (December 2003), the USNRC has approved 16 revisions of the TRUPACT-II Certificate of Compliance.[2] The USNRC has also approved one revision of the Half-PACT Certificate of Compliance (see Section 3.3). The Department of Energy (DOE) has submitted a request for Revision 17 of the TRUPACT-II Certificate of Compliance and Revision 2 of the Half-PACT Certificate of Compliance; these requests are currently being reviewed by the USNRC. These applications, among other things, are seeking to provide a consistent format, content, and layout for the Safety Analysis Reports (SARs), as well as to update payload requirements for TRUPACT-II and HalfPACT (Gregory, 2002). Sections D.1 through D.6 describe the transportation package requirements necessary to ship waste in a TRUPACT-II or Half-PACT, while Section D.7 compares transportation requirements to ship TRU waste to WIPP with those for shipments between DOE TRU waste generator sites.

WIPP transportation package requirements originate from U.S. Department of Transportation (DOT) regulations (49 CFR 171–179) for shipments of all hazardous materials and USNRC regulations (10 CFR 71) for Type B[3] and radioactive material packages. These requirements are implemented in the TRUPACT-II Authorized Methods for Payload Control (TRAMPAC), which is the primary governing document for TRUPACT-II authorized contents (payload containers). The TRAMPAC is a document specific to all shipments in TRUPACT-IIs, regardless of the destination (WIPP or other DOE sites). The following is a digest of the TRAMPAC basic requirements for the TRUPACT-II.

[1]In the context of transportation requirements, the term “shipping container” describes the TRUPACT-II or HalfPACT, whether empty or loaded, while the term “payload container” describes a 55-gallon drum, standard waste box, or ten-drum overpack that is shipped in the TRUPACT-II or HalfPACT and subsequently disposed of at WIPP. The terms “contents” or “container” usually refer to the waste inside the payload container.

[2]Current certificates of all USNRC and DOE-certified packages are available at: <http://www.rampac.com>.

[3]The DOT regulates the design of Type A packages for the various size drums, such as standard waste boxes and ten drum overpacks. For a definition of Type A and B packages, see the Glossary.

D.1 CONTAINER AND PHYSICAL PROPERTIES REQUIREMENTS

The following are the TRAMPAC requirements concerning the payload container and its physical properties:

- *Container and physical properties.* Descriptions of the payload containers that are authorized by the USNRC for shipment in TRUPACT-II follow: 55-gallon drum, 100-gallon drum, standard waste box (SWB) three types of pipe overpacks,[4] and the ten-drum overpack (TDOP). Compliance is met by using one, or more, of the following methods: administrative and procurement controls,[5] visual inspection to the U.S. Department of Transportation (DOT) Type A packaging requirements (49 CFR 178.350), or equivalent requirements.
- *Dunnage.* These empty payload containers are used to complete a payload assembly if not enough payload containers loaded with waste are available to meet the transportation requirements. Visual inspection is used to verify compliance with TRAMPAC dunnage container specifications.
- *Container and assembly weight limits and center of gravity.* The loaded TRUPACT-II weight limit is 19,250 pounds. The weight limit for the Half-PACT is 18,100 pounds. Requirements on center of gravity of the TRUPACT-II are also specified in the TRAMPAC. Compliance with weight limits is verified by measurement.
- *Container marking.* Each payload container has a unique identification number. Visual inspection is used to verify compliance with requirements.
- *Filter vents.* The purpose of filter vents is to ensure the diffusion of gases from the payload container. In addition, any rigid liners in the payload containers are punctured or vented to ensure the diffusion of gases within the payload container. Under a quality assurance program, test methods are used to determine the compliance of filter vents with TRAMPAC specifications. One or more of the following methods are used to verify compliance: administrative and procurement controls, visual inspection, and sampling.
- *Liquids.* These are prohibited in the payload containers, other than residual amounts in well-drained containers. The total volume of residual liquid is limited to less than 1 percent of a payload container.[6] Compliance is verified using one or more of the following methods: administrative and procurement controls, real-time radiography (RTR), visual examination, and a statistical sampling program.
- *Sharp or heavy objects.* Such objects are blocked, braced, or packaged to prevent them from puncturing payload containers. Compliance is verified using one or more of the following methods: administrative and procurement controls, RTR, visual examination, and a statistical sampling program.
- *Sealed containers.* Sealed containers of more than 4 liters are prohibited except for waste material Type II.2 packaged in a metal container (solid inorganic

[4]For a definition of overpack, see the Glossary.

[5]Administrative and procurement controls are site-specific controls to show that the payload container contents are monitored and controlled and to demonstrate the absence of prohibited items. Some of the characterization information gathered for EPA and NMED can be used for this purpose.

[6]The 1 percent limit on free liquids is not specific to WIPP but also applies to USNRC regulations on low-level waste disposal (see 10 CFR 61.56). The purpose of this threshold is to ensure that solid waste contains as little free-standing and noncorrosive liquid as is reasonably achievable.

materials in metal cans do not generate flammable gas).[7] Compliance is verified using one or more of the following methods: review of records and database information, RTR, visual examination, and a statistical sampling program.

D.2 NUCLEAR PROPERTIES REQUIREMENTS

The following are the TRAMPAC nuclear properties requirements for waste shipped to WIPP or an interim site:

- *Nuclear criticality.* A TRUPACT-II is acceptable for transport only if the FGE (fissile gram equivalent) value is less than or equal to the applicable limit for each payload container. The limits for a 55-gallon drum, standard waste box, and 10-drum overpack are 200, 325, and 325 FGE of plutonium-239, respectively.[8] Complying with the FGE requirements involves determining the isotopic composition and quantity of radionuclides; calculating the FGE; and recording it in transportation certification documents. The isotopic composition of the waste may be determined from review of records and database information. If this information is not available, direct measurements or assay of the waste should be conducted during the processing or post-process certification at each site. The quantity of radionuclides in each payload container is estimated by either direct measurement or analysis of the payload container's records, summation of assay results from individual packages in each payload container, or direct measurement on a representative sample of a waste stream.
- *Radiation dose rates.* External radiation dose rates of individual payload containers should be equal to or less than 200 mrem per hour at the surface and equal to or less than 10 mrem per hour at 2 meters. Prior to shipment, measuring and recording the payload container and TRUPACT-II surface dose rates, and the dose rate at 2 meters, verify compliance with this requirement.

D.3 CHEMICAL PROPERTIES REQUIREMENTS

The following are the TRAMPAC chemical properties requirements to ship TRU waste to WIPP or an interim site:

- *Pyrophoric materials.*[9] Pyrophoric materials are generally prohibited in payload containers except for small residual amounts (less than 1 percent by weight). Before being placed in a payload container, radioactive pyrophoric materials in concentrations greater than 1 percent by weight and all nonradioactive pyrophoric materials are rendered nonreactive. Administrative and procurement controls can be used to verify compliance with this requirement.
- *Explosives, corrosives, and compressed gases.*[10] These are prohibited from payload containers. Compliance with this requirement is verified by using one or

[7]The 1-gallon limit (later revised to 4 liters) was a threshold agreed upon between DOE and the USNRC. One-gallon sealed containers are occasionally present in legacy waste. The basis for this requirement is the principle of keeping workers exposure as low as reasonably achievable. The USNRC agreed with DOE that requiring workers to open and remove containers smaller than 1 gallon is not necessary to ensure compliance with regulations.

[8]These container-based limits expressed in total grams per enclosed volume originate in criticality considerations, so that specific location of fissile material within the drum need not be known.

[9]For the definition of pyrophoric material, see the Glossary.

[10]For the definitions of explosives, corrosives, and compressed gas, see the Glossary.

more of the following methods: visual examination, administrative and procurement controls, RTR, or a sampling program.

- *Chemical composition.* A conservative bounding G value of the potential gas generation of each waste material type is established by restricting the chemical constituents of each waste type.[11] The total quantity of trace chemicals or materials not listed as allowed materials in any payload container is restricted to less than 5 percent by weight. Compliance is verified by administrative and procurement controls or a sampling program.
- *Chemical compatibility.* Payload materials are analyzed for their chemical compatibility according to the EPA document, *A Method for Determining the Compatibility of Hazardous Wastes* (1980). Restrictions imposed on the chemical constituents of the content codes ensure compliance with the compatibility requirements (DOE-TRAMPAC, 2003; page 4–4). Chemical compatibility of payload container materials must meet the following conditions: chemical compatibility of the waste forms within each individual payload container, chemical compatibility of the waste with the TRUPACT-II inner containment vessel and the TRUPACT-II seals, and chemical compatibility between the contents of payload containers during hypothetical accident conditions.

D.4 GAS GENERATION REQUIREMENTS

The following are the gas generation requirements to ship TRU waste to WIPP or an interim site:

- *Maximum allowable hydrogen generation.* The following two restrictions apply to any package containing water and/or organic substances that could generate combustible gases radiolytically: 1) over a period of time twice the expected shipment time, the hydrogen (or any other flammable gas) generated is limited to no more than 5 percent by volume of the innermost layer of confinement. 2) Gases generated in the payload and released into the TRUPACT-II inner containment vessel cavity must be controlled to keep the pressure within the cavity below the acceptable design pressure of 50 pounds per square inch gauge. Testing and measurement, or analysis of a representative package is used to determine gas concentrations and pressures.
- *Payload shipping category.* To determine the total resistance to gas release of a payload container, the type and maximum number of layers of confinement used to package the waste must be known and documented. Each payload container is assigned a shipping category that includes the following information: waste type, waste material type (which defines the gas generation potential), and total resistance to gas release by the approved packaging confinement layers (including rigid liner). Appropriate forms should be completed with the appropriate content codes from the transuranic content codes (TRUCON) document for the shipping categories. Compliance with requirements for total resistance should be verified using the following methods: for confinement layers, by using RTR, visual examination, administrative and procedural controls, or a combination of these methods; for the rigid liner (greater than a 0.76 centimeters-or 0.3-inch diameter hole or fitted filter vent) by procurement controls and site quality assurance procedures combined with visual examination of the liner prior

[11]For the definition of G value, see the Glossary.

to closure, or by using either RTR or sampling programs combined with review of records and database information.

- *Compliance with flammable gas or volatile organic compound (VOC) concentration limits.* TRUPACT-II payload containers are classified into two categories based on their compliance with the flammable gas or VOC limits. 1) In the analytical category, flammable VOCs are restricted to less than or equal to 500 parts per million (ppm) in the payload container headspace, and a bounding G value is used to conservatively estimate the potential for flammable gas generation. To meet the 5 percent limit on hydrogen concentration, a decay heat limit is used as a surrogate for gas measurements. This limit restricts the amount of radioactive material that can be present in the payload container. 2) Payload containers that do not meet the analytical category limits are placed in the test category where compliance with flammable gas or VOC limits is determined either by measuring the headspace of the payload containers for flammable gas or VOC concentrations and determining the potential flammability of the mixture in the innermost layer of confinement during transportation or by full-drum testing to determine compliance with flammable gas or VOC limits for individual 55-gallon drums (see Section 4.1 on gas generation tests).
- *Decay heat.* This is heat produced by the decay of radionuclides in the waste. Decay heats for each payload container are determined from the isotopic composition and are expressed in watts. The sum of the decay heat for each payload container must be equal to or less than the limits specified in Table 5.5–1, Appendix 5.5 of the TRAMPAC. Because of the potential for hydrogen buildup, shipment times to WIPP must not exceed a maximum of 60 days. Certain waste from Los Alamos National Laboratory was granted an exemption to this shipping time requirement because of the short distance to WIPP and was the object of Revision 19a of the SARP (DOE-SARP, 2003).

D.5 PAYLOAD ASSEMBLY REQUIREMENTS

These are control procedures that sites use to assemble a payload that is qualified for transport in TRUPACT-II. Each payload container has an assigned shipping category and content code. The measured parameters (weight, fissile material, and decay heat) are checked against the parameter limits of the TRAMPAC document. If the payload container does not meet the limits, it will not be approved for transport ("subject to mitigation or repackaging") and will be marked and separated from other payload containers. The procedures for certifying the payload container and its assembly are found in Appendix 6.2 of the TRAMPAC.

D.6 QUALITY ASSURANCE

The following are the transportation quality assurance requirements to ship TRU waste to WIPP or an interim site:

- *Transportation quality assurance requirements.* Quality assurance requirements applicable to the use of TRUPACT-II packaging are derived from 10 CFR 71, Subpart H. Certification of authorized contents for shipment in TRUPACT-II is performed under a written quality assurance program that provides confidence, for both the shipper and the receiver, that TRAMPAC requirements have been met. DOE-CBFO (Carlsbad Field Office) conducts a compliance-verification audit prior to the first shipment and periodically thereafter to ensure compliance with TRUPACT-II requirements and WIPP Waste Acceptance Criteria. Compliance with transportation requirements applies to the following two categories of waste, depending on the time of generation:

1. *Waste Generated under a formal certification program.* Payload containers in this category (designated “100 Series”) are characterized individually based on process knowledge and visual examination at the time of waste generation. For sites using a set of site or equipment-specific procedures for payload control for compliance, an independent verification of compliance must be performed prior to transport for no less than 10 percent of the 100 Series payload containers transported from each site per year. This independent verification may consist of a second operator verifying the payload container contents or waste records during the waste generation process or RTR.
2. *Waste generated prior to site implementation of a formal certification program.* Payload containers in this category (designated “200 Series”) are characterized based on process knowledge. An independent verification of compliance must be performed prior to transport for 200 Series waste using visual examination, RTR, and measurement under a statistical sampling program.

D.7 REQUIREMENTS FOR INTERSITE SHIPMENTS

Transuranic waste can be shipped between two DOE sites without having to comply with all of the characterization requirements that apply to shipments to WIPP. Table D.1 compares requirements for WIPP shipments to those for intersite shipments. Intersite shipments require compliance with packaging and transportation requirements and with the receiving site's Waste Acceptance Criteria. Characterization requirements for shipments to WIPP include requirements for disposal, which obviously are not required for intersite shipments. Note that receiving sites' Waste Acceptance Criteria typically require a “fingerprint” of the waste. Fingerprinting refers to tests that waste facilities regulated under the Resource Conservation and Recovery Act perform to ensure that the incoming waste meets permit requirements. Fingerprinting is not allowed at WIPP.

Table D.1 Comparison of Characterization Requirements for Intersite Shipments and Shipments to the Waste Isolation Pilot Plant

WIPP Shipments	Intersite Shipments
DOT Hazardous Waste Manifest[a]	DOT Hazardous Waste Manifest[a]
Use only USNRC-approved packaging	Any USNRC-, DOE-certified Type B,[a] or DOT-specification packaging
WIPP site Waste Acceptance Criteria[a]	Receiving site's Waste Acceptance Criteria
-WIPP Safety Analysis Report[a]	-Receiving site Safety Analysis Report
-EPA and NMED Permit(s)	-Permit(s) issued by EPA and/or state
-USNRC Certificate of Compliance	-Fingerprint[a] upon receipt
-Prescriptive Waste Analysis Plan[a]	
-Site specific procedures	
-Approved characterization plan	
-Audit prior to shipment	

[a]See the Glossary.
SOURCE: Gregory, 2003.

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E

Health and Safety Issues in Waste Characterization

This appendix contains information on health and safety issues related to transuranic (TRU) waste characterization activities gathered during this study. The information presented was provided by the U.S. Department of Energy (DOE) or its contractors and has not been independently verified by the committee. Most of the discussion below refers to risks to workers during routine operations.

E.1 WASTE HANDLING AND MANAGEMENT AT GENERATOR SITES AND WIPP

It is largely at the waste generator sites that TRU waste is handled and managed. Waste handling and management at generator sites include retrieving waste from its location to prepare it for shipment, repackaging, and characterization activities. Activities at the Waste Isolation Pilot Plant (WIPP) are associated primarily with temporary storage of waste and emplacement in the repository.

There are four general worker categories (see Table E.1): radiation control technicians (RCTs) who monitor radiation levels during drum handling and emplacement activities; waste handlers (WHs) who manipulate and move drums; drivers who transport waste; and other workers, including engineers, analysts, and maintenance workers who support waste processing activities but are not otherwise directly involved with waste processing. Since the beginning of WIPP operations, a small number of radiation control technicians, waste handlers, and drivers have received measurable radiation doses (see Table E.1). These doses are attributed to waste characterization-related activities. The frequency of measured doses to RCTs and WHs at generator sites have increased considerably since 1999 because of the significant increase in shipments to WIPP from 1999 through 2002, although fewer drivers received measurable doses in 2002 compared to 1999. Since 1999, more than 80 percent of WIPP workers have served in the “other” workers category shown in the table and have a low frequency of measured doses. In all cases, the doses to workers have been well below regulatory limits.

Table E.1 Radiation Monitoring at the Waste Isolation Pilot Planta

Year	Radiation Control Technicians	Waste Handlers	TRU Waste Drivers	Other Workers
1999	24/1	19/3	12/3	349/13
2000	24/1	20/2	12/1	466/1
2001	33/8	22/6	36/12	467/34
2002	43/21	43/28	71/8	446/32

[a]Number of workers monitored versus number of workers with measured radiation doses. Other workers include engineers, mine operations personnel, and maintenance workers. Data for 2002 do not include last quarter.
SOURCE: Nelson, 2003.

The New Mexico Environmental Evaluation Group (EEG) published its analysis of risks at WIPP to both workers and the general population from radiation and hazardous material exposure associated with routine operations both above and underground, risks from accidents involving the release of radioactive and hazardous material, and risks associated with disposal of the waste (EEG, 1999). However, the authors did not calculate the risks associated with characterization activities, all of which occur at the generating sites. Nonetheless, two of the major conclusions in the EEG (1999) report are applicable to workers conducting characterization activities at the generating sites:

1. the relative carcinogenic risks of radioactive exposure to workers are several orders of magnitude greater than the carcinogenic risks from the hazardous waste constituents; and
2. the risks for both the potential radiation exposure and the exposure to hazardous waste constituents are low.

E.1.1 Worker health

The predominant radiation exposure pathways for workers from routine waste handling activities are direct exposure to external penetrating radiation or inhalation from surface contamination, and inhalation of airborne radioactive material generated during waste handling activities. Radiation doses to workers depend on quite a few factors, including the number of drums processed, their surface dose rate, the amount of drum handling, the isotopic mix of the waste and radiological nature and amount of the radionuclides (particularly the amount of Americium-241), the types of sampling and measurements conducted, the number of workers involved, worker experience and training, and equipment and shielding.

Activities associated with processing contact-handled transuranic (CH-TRU) waste for burial at WIPP may result in worker exposures to chemical agents (e.g., volatile organic compounds [VOCs]), and radionuclides. In the three years of WIPP operations, the major source of health risks to workers has been from exposure to radionuclides. VOC exposures have not been documented at WIPP because VOC concentrations in open rooms are very low. Based on an inventory of approximately 37,000 drums, the total VOC content integrated over all headspace gas levels is approximately 175 liters (vapor phase). About 50 percent of the volume is acetone, with 90 percent of the remainder made up of 1,1,1-trichloroethane, toluene, methylene chloride, and carbon tetrachloride. The only way to detect the presence of VOCs in the underground (other than tallying the headspace gas measurements made during characterization) is to collect ambient samples in the stagnant air behind the curtains used to isolate each disposal room when it has been filled. The concentration measured in closed rooms (from the drums “breathing” through their vents) is on the order of 100 parts per billion by volume (ppbv). Measurement of the air in routine flows in the rest of the mine (including drifts downstream of the disposal rooms) has always shown less than detectable levels (approximately 5 ppbv) to date (Nelson, 2003).

The waste received to date has contained very low levels of VOCs in the headspace gas. It is possible that some future waste streams will contain significantly greater VOC concentrations in the headspace gas. In a recent estimate, DOE states that even when taking into account all solidified organic wastes in the DOE TRU complex (less than 2,000 cubic meters stored and projected), there is no threat of exceeding WIPP emission standards (McCulla and Van Soest, 2003). Earlier estimates of VOC concentrations in disposal rooms by the New Mexico Environmental Evaluation Group

(EEG-72) were published in 1999 (EEG, 1999).[1] Given more recent experimental data, it is unlikely that the concentrations predicted in EEG-72 will ever be realized in the actual waste and operations over WIPP's lifetime.

E.1.2 Public health

Public health risks from routine operations at generator sites (estimated by considering exposures to members of the public living at the site boundary) and at WIPP are minimal and often not measurable. Only a very small fraction of workers receives measurable doses at WIPP; accordingly, members of the general public would not be expected to have any measurable doses off-site as long as the area is not penetrated by drilling or by other means, which could bring waste to the surface or come in contact with groundwater.

E.2 TRANSPORTATION

Currently, CH-TRU is transported to WIPP from generator sites via highway in TRUPACT-II shipping containers. Because of the integrity and durability of Type B packages under extreme accident test conditions, risk-based characterization requirements for TRU waste shipments are focused mainly on limiting the flammable gas-generating potential of TRU contents and ensuring that no prohibited items such as pressurized containers are present. In addition, characterizations of CH-TRU waste are performed to limit potential doses to the public during normal conditions and to prevent possible criticality by limiting the amount of contained fissile material.

E.2.1 Worker health

Radiation doses to drivers can be measured using conventional personnel monitoring. Radiation doses to truck drivers are caused by TRUPACT-II external dose rates, the distance between the truck driver and the transportation package, and transit time. Since 1999, more than 3,000 TRUPACT-II packages have been received at WIPP, primarily from the Idaho National Engineering and Environmental Laboratory and the Rocky Flats Environmental Technology Site, involving over 300 truck drivers (Nelson, 2003). Only 25 drivers have received measurable radiation doses. The average annual dose per driver (including drivers with no measurable dose) is 2 mrem; the maximum dose received was 39 mrem (Nelson, 2003).

E.2.2 Public health

Radiation doses to the public from characterization activities related to transportation and from transportation itself are difficult and impractical to measure. Doses and risks can be estimated from modeling studies, which have shown that doses are insignificant in normal operating conditions (40 CFR 194-final rule). On the basis of these results, the U.S. Environmental Protection Agency (EPA) granted a Certificate of Compliance allowing WIPP to operate.

The highest risk to the public due to waste transportation is from road accidents involving trucks transporting radioactive waste. The actual risk is that of being injured by the collision forces of the vehicles involved. Most, if not all, of these accidents occur without the release of radioactivity.

[1]Health risks from VOC exposures based on WIPP operations are expressed as order of magnitude estimates because of the large uncertainties involved. The EEG-72 predicted source term is about 1,000 times greater than VOC concentrations actually measured in waste drums emplaced in WIPP. If all other risk model parameters remain the same, risks to workers and the public from WIPP operations would be 1,000 lower than risks predicted in EEG-72.

Transportation accidents are inevitable because of the large number of shipments to WIPP. DOE estimates that over a 35-year period, WIPP would receive more than 37,000 shipments of TRU wastes from waste generator sites, which would result in five traffic fatalities (DOE-FSEIS, 1997, page E-28, Table E-9). Three minor transportation incidents involving WIPP shipments have occurred to date (see Appendix F). In no case there was any release of radioactive material from the shipping container.

Potential transportation risks to the public associated with the waste itself relate almost entirely to any exposure to toxic materials or radioactivity during accidents. However, even in the most severe accident scenarios involving Type B (see the Glossary) transportation packages, loss of containment with release of radioactivity is considered unlikely. For instance, EEG estimated that there will be one accident of sufficient severity in 37,000 shipments to result in the release of radioactivity (EEG, 1990).

E.3 CASE STUDY: SAVANNAH RIVER SITE OPERATIONS

The Savannah River Site is a major processing and characterization hub for sites having relatively small amounts of CH-TRU waste (small-quantity sites). In addition to generating its own waste, the Savannah River Site also processes and characterizes waste from more than 15 off-site generators, of which Mound Laboratory is the largest. The Savannah River Site has approximately 11,000 cubic meters of legacy waste for disposal at WIPP. This site made its first shipment to WIPP in May 2001 (DOE-SRS, 2003a).

To close Mound by 2005, DOE entered into an agreement with the State of South Carolina stipulating that, for every 2 cubic meters of waste shipped from the Savannah River Site to WIPP, 1 cubic meter of waste could be shipped to the Savannah River Site from Mound. DOE quickly implemented the Centralized Characterization Project to supplement the Savannah River Site's characterization capabilities. Mobile units performing nondestructive assay, real-time radiography (RTR), and headspace gas sampling activities, and TRUPACT-II loading were deployed at the Savannah River Site in 2002. With operational experience, the site's staff implemented a time-saving practice that is not required by the Hazardous Waste Facility Permit (HWFP): to provide a sufficient number of drums for the next week's activities, drums are “fast-scanned” for prohibited items using the mobile RTR equipment prior to starting characterization activities. Drums rejected during the fast scan, or during the regular RTR, are removed from the process and stored (DOE-CABE, 2003). To date (December 2003), the removal of prohibited items (rework activities) has not started. This practice limits the “dance of the drums” (see Section 4.6) and improves the time-efficiency of the waste characterization process.

E.3.1 Worker doses and risks from operations

During calendar year 2002, the Savannah River Site processed and characterized 3,774 CH-TRU waste drums for transportation to WIPP. The collective dose to the 83 persons processing, characterizing, or transporting these drums was 2,694 person-mrem (DOE-SRS, 2003b). About 15 percent of this collective dose was received by two individuals engaged in removing material from drums and visually examining them. Given an average dose of 33 mrem per person, the radiogenic health risk is very small and may be considered insignificant. The uncertainty in risk at this dose level is so large that the lower bound of uncertainty extends to zero (NRC, 1990).

The average surface dose rate for the drums processed in 2002 was less than 0.2 mrem per hour (DOE-SRS, 2003b), suggesting very low quantities of Americium-241 in the waste characterized that year. Review of the isotopic distribution records of CH-

TRU waste at the Savannah River Site indicates considerable variability in Americium-241 activity (DOE-FEIS, 1997). The isotopic mix varies substantially from year to year; from 1970 to 1995, waste streams at the site had Americium-241 activity ranging from zero to 546 curies. Waste retrieval and packaging for shipment to WIPP involve the entire inventory, (i.e., drums and culverts are selected for characterization without consideration of isotopic mix).

E.4 CASE STUDY: ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Rocky Flats Environmental Technology Site has had more experience than any other site in the processing and management of TRU waste. This site sent the first shipment of CH-TRU waste to WIPP on June 16, 1999. As of December 2003, more than 1,000 shipments have been made from Rocky Flats to WIPP. Rocky Flats is in the terminal phase of its operations and it is projected that the facility will complete waste processing and shipments by 2006.

Plutonium "pits" used in the manufacture of nuclear weapons were produced at the Rocky Flats Environmental Technology Site. Consequently, most of the Rocky Flats waste consists of waste contaminated with Plutonium-239. Plutonium is an alpha emitter and produces significant neutron dose rates when the alpha particles interact with low-atomic-number elements in the waste. There is also a gamma-ray component to the container surface dose rate due to the presence of Americium-241.

High-temperature processing was one of the steps involved in the production of plutonium pits. Therefore, DOE negotiated with the New Mexico Environment Department, an exemption from the headspace gas sampling and analysis requirement for some of the Rocky Flats Environmental Technology Site TRU waste, because thermally treated waste cannot contain any residual volatile organic compound (see Chapter 3). Some of the TRU waste at the Rocky Flats Environmental Technology Site was also solidified in a cement matrix.

In 1992, nuclear weapons-related production was halted at Rocky Flats, and DOE began the processes of decontamination and decommissioning of buildings and environmental restoration. A very large amount of alpha-contaminated gloveboxes, piping, fluoride salts, equipment, and scrap material had to be processed for packaging and shipment, in addition to a substantial amount of contaminated soil in the surrounding areas.

E.4.1 Workers doses and risks from operations

In 2002, 215 persons (including waste handlers, on-site transporters, and others involved in drum processing) were monitored. Of these, 205 had measurable exposures. The collective dose to all monitored persons was 36,800 person-millirem for 2002. The average surface dose rate for processed containers is 6.57 mrem per hour.

Workers at the Rocky Flats Environmental Technology Site have an order-of-magnitude higher exposure than those at Savannah River Site, although it is still small relative to permissible limits. The increased worker exposures are due to handling and processing containers with significantly higher surface dose rates. Retrieving drums of approved waste from storage locations at the Rocky Flats Environmental Technology Site required moving non-approved waste drums out of the way to allow access to the desired drum (the so-called dance of the drums, see Section 4.6). With operational experience, less time is expended looking for a single drum, and the drum mining and moving operations have been minimized (DOE-CABE, 2003).

Drum handling and processing experience and use of best available practices have resulted in significant reductions in personnel exposures. Radiation exposure received by personnel in the shipping facilities at the Rocky Flats Environmental

Technology Site (Buildings 440 and 664) has been used to document trends in personnel dose related to WIPP operations. In 2000 the cumulative dose per shipment was 250 mrem; in 2003 the cumulative dose per shipment was reduced to 50 mrem. The information gathered on the Rocky Flats site indicates that streamlining the characterization process can have a beneficial impact on worker doses (Spears, 2003). Surface dose rates from drums originating from the Rocky Flats Environmental Technology Site average approximately 1 mrem per hour (about 100 of the 19,000 drums emplaced at WIPP had surface dose rates in excess of 10 mrem per hour).

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F

Risk Considerations

This appendix presents examples of issues to be included in the kind of analysis proposed to determine the linkage between waste characteristics and risks in handling, transportation, and disposal of contact-handled transuranic (CH-TRU) waste at the Waste Isolation Pilot Plant (WIPP). Constrained by both time and information, the committee could only point out some of the risks to be included in this risk analysis; a complete risk assessment is a major endeavor that the committee was not prepared to undertake.

F.1 RISKS RELATED TO WASTE HANDLING

Risks to workers related to waste handling may arise in the recovery, characterization, and packaging of waste during operations at the generator sites; in transportation; and during receipt, temporary storage, and waste emplacement operations at WIPP. Worker exposures to the hazardous and radioactive constituents of the waste (through exposure to external radiation, inhalation, dermal contact, and ingestion) and industrial-type accidents are the main risk concerns. Hazardous material risks arise from potential exposures to hazardous metals (including beryllium, cadmium, lead, and mercury) and organic compounds, especially volatile organic compounds (VOCs).

Generally, experience has shown that the more waste handling that is required to perform a given characterization activity, the greater the worker radiation doses. The collective worker dose has increased since WIPP opened and began to receive waste in 1999 because of the increase in number of shipments received. However, the collective dose to a population provides little specific information about individual dose. Despite the increase in shipments and collective dose, the average annual worker dose has not varied significantly since 1999. Worker doses at WIPP have averaged only 1–2 mrem per year for all monitored workers; and no exposure has been reported for a majority of monitored workers. This is very low in comparison to the applicable permissible regulatory dose limit of 5,000 mrem per year, reflecting in part waste characterization being performed at the generator sites before shipment to WIPP. At the generator sites where the characterization is performed, worker doses are higher, but still well below the regulatory limits.[1]

Overall, doses to workers in normal operating conditions remain well below regulatory limits largely because DOE is taking appropriate measures to protect workers (see Appendix E). Public health risks from routine operations were estimated by considering exposure of members of the public living at the site boundary. Exposures have been so small that they have not been measurable in the presence of background radiation. Short-term operational risks in the proposed analytical framework would consider accident scenarios, such as fires, explosions, floods, or loss of containment

[1] Two case studies for worker radiation dose at generator sites are presented in Appendix E: the Savannah River Site and the Rocky Flats Environmental Technology Site.

involving waste containing prohibited items (e.g., liquids) both at generator sites and at WIPP.

F.2 RISKS RELATED TO TRANSPORTATION

Currently, CH-TRU waste is transported to WIPP from generator sites via highway in a TRUPACT-II shipping containers. Studies have shown that radiation exposure to workers during transportation is well below regulatory limits under normal operating conditions (EEG, 1990; Neill and Neill, 2000). Even in the most severe accident scenarios involving Type B transportation packages,[2] loss of containment with release of radioactivity and exposure is considered unlikely (DOE-FSEIS, 1997).[3] Occasional transportation accidents are inevitable because of the projected large number of shipments to WIPP. DOE estimates that over a 35-year period, WIPP will receive more than 37,000 shipments of TRU wastes from waste generator sites (DOE-FSEIS, 1997). Three minor transportation incidents involving WIPP shipments have already occurred since WIPP opened.[4] In no case was the event serious, nor was there any release of radioactive material from the shipping container.

To reduce the number of shipments, DOE is investigating the potential for requesting further modifications to the TRUPACT-II Certificate of Compliance to increase the amount of waste in each shipment. Although DOE has not yet made a formal submission to the U.S. Nuclear Regulatory Commission (USNRC), there has been substantial interaction between the staffs in considering the risk of the 5 percent hydrogen generation limit to the health and safety of workers involved in the repackaging of waste

Transportation risks are often at the heart of stakeholders' concerns at generator sites, in New Mexico, and in corridor states (see Section 4.6.4). These concerns revolve primarily around accident consequences, and include concerns that, if waste is characterized using non-certified procedures, it has the potential to be out-of-compliance. Transportation risks to be addressed in these cases include the probability and consequences of transporting waste containing prohibited items, such as liquids. Also to be considered is the increased transportation risk from returning a shipment to a generator site because it is found to be out of compliance.[5]

F.3 RISKS RELATED TO WASTE DISPOSAL

Short-term operational risks at WIPP are discussed in Section F.1. Long-term risks related to waste disposal include operational risks if waste retrieval is necessary (e.g., waste "mining" accidents) and risks if the repository is breached (e.g., release of radioactivity into the environment).

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[2]For a definition of Type B transportation package, see the Glossary.

[3]Although DOE never specified the probability of an accident with a release of radioactivity, DOE estimated a total of 0.4 latent cancer fatalities and 850 person-rem from "severe" transportation accidents (DOE-FSEIS, 1997).

[4]In November 2000, a TRUPACT-II truck drove down a non-authorized road for about 27 miles before it was stopped by the state Police and re-directed to WIPP. In August 2002, a privately-owned vehicle hit a TRUPACT-II truck. Radioactivity contamination was found inside the inner containment vessel of the TRUPACT-II but it is unclear whether it was related to the accident. In any event, no radioactive release to the environment was detected. In September 2002, a TRUPACT-II truck driver lost consciousness causing the truck to cross the interstate median and end in a level field (DOE-CBFO, 2003).

[5]Such a scenario occurred in August 2002. A TRUPACT-II truck upon inspection at WIPP was returned to the Idaho Engineering and Environmental Laboratory because radioactive contamination was detected in the inner vessel of the shipping container (DOE-CBFO, 2003).

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Glossary

20.4.1 (New Mexico Administrative Code [NMAC] Chapter 20, Section 4, Part 1): New Mexico Environment Department. Establishes the regulations for the management of hazardous waste consistent with the New Mexico Hazardous Waste Act and federal Resource Conservation and Recovery Act (RCRA) regulations, Title 40 Code of Federal Regulations (CFR) Parts 260 through 270.

20.4.1.200: New Mexico Environment Department (NMED). This regulation (incorporating Title 40 CFR Parts 261.24, 261.31, and 361.33) requires the U.S. Department of Energy (DOE) to identify and list hazardous wastes.

20.4.1.500: New Mexico Environment Department. This regulation (incorporating Title 40 CFR 264) requires DOE to conduct a detailed analysis of the hazardous waste components of transuranic mixed waste to obtain all of the information on how to treat, store, or dispose of the waste. DOE must demonstrate that the design and operation of the facility will minimize the possibility of the release of transuranic mixed waste, a fire, or an explosion. NMED prohibits the following at WIPP:

1. liquid waste;
2. pyrophoric materials;
3. non-mixed hazardous wastes;
4. chemically incompatible wastes;
5. explosives and compressed gases;
6. polychlorinated biphenyl (PCB) concentrations;
7. ignitable, corrosive, and reactive waste; and
8. remote-handled transuranic mixed waste.

20.4.1.900: New Mexico Environment Department. This document contains the hazardous waste permit program requirements issued by the NMED (incorporating 40 CFR 270). These requirements must be met by DOE to receive NMED approval of the Waste Analysis Plan submitted as Part B of the permit application (see *Hazardous Waste Facility Permit*) for mixed transuranic waste.

10 CFR 20: (Title 10 Code of Federal Regulations Part 20): U.S. Nuclear Regulatory Commission (USNRC). Standards for Protection Against Radiation.

10 CFR 71: USNRC design requirements for Type B transportation packages.

10 CFR 835: U.S. Department of Energy. Occupation Radiation Protection. Establishes standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from DOE activities.

40 CFR 191: U.S. Environmental Protection Agency (EPA). Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, Final Rule. December 20, 1993. *Federal Register* (FR) 58(242):66398–66416. This regulation prescribes EPA environmental radiation protection standards that will apply to all sites (except Yucca Mountain) for the deep geologic disposal of highly radioactive waste. Congress required EPA to evaluate whether the Waste Isolation Pilot Plant (WIPP) complies with Subparts B and C of the disposal regulations set forth in this document for the management and disposal of transuranic radioactive wastes.

40 CFR 194: U.S. Environmental Protection Agency. Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's compliance with 40 CFR Part 191 Disposal Regulations, Final Rule. May 18, 1998. *Federal Register* 63(95):27353– 2740. This regulation stipulates that DOE must provide a list to the EPA that identifies and describes waste characteristics that can impact WIPP's performance. This list may be derived from methods that include process knowledge and nondestructive assay or examination. On May 18, 1998, EPA issued a final rule certifying that WIPP was compliant with applicable EPA transuranic (TRU) waste disposal regulations set forth in 40 CFR 191 and the compliance criteria of 40 CFR 194 (63 FR 27354).

40 CFR 194.22(b): U.S. Environmental Protection Agency. This section includes the quality assurance requirements for waste characterization activities and assumptions. The quality assurance provisions allow the characterization of waste by 1) peer review 2) corroboration with new data, 3) confirmation by measurement, or 4) qualification of previous quality assurance (QA) programs.

40 CFR 261: U.S. Environmental Protection Agency. Identification and Listing of Hazardous Waste. This part identifies those solid wastes that are subject to regulation as hazardous wastes under Parts 262–265, 268, 270, 271, and 124 of Title 40 of the Code of Federal Regulations. Codified in New Mexico as 20 NMAC 4.1, Subpart II.

40 CFR 264: U.S. Environmental Protection Agency. This part consists of “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” This subpart establishes minimum national standards that define the acceptable management of hazardous waste. Codified in New Mexico as 20 NMAC 4.1, Subpart V.

40 CFR 270: U.S. Environmental Protection Agency. This regulation establishes provisions for the Hazardous Waste Permitting Program under Subtitle C of the Resource Conservation and Recovery Act. This regulation and the associated State of New Mexico regulations require the permitting of WIPP as a hazardous waste management unit. Codified in New Mexico as 20 NMAC 4.1, Subpart IX.

49 CFR 171–180: U.S. Department of Transportation regulations for transporting hazardous material addressing issues, such as payload container types, transportation modes, route designations, and emergency response and training.

Acceptable Knowledge (AK): A term used by the EPA that encompasses process knowledge and results from previous testing, sampling, and analysis of waste. AK includes information regarding the raw materials used in a process or operation, process description, products, and associated wastes. AK documentation includes the site history and mission, site-specific processes or operations, administrative building controls, and all previous and current activities that generate a specific waste.

ALARA (As Low As Reasonably Achievable): Radiation protection program for minimizing personnel exposure to radiation. ALARA means making every reasonable effort to maintain exposures to radiation as far below the dose limits in the DOE guidance as is practical consistent with the purpose for which the activity is undertaken.

Audit: A planned and documented investigative evaluation of an item or process to determine its adequacy and effectiveness as well as compliance with established procedures, instructions, drawings, and other applicable documents.

Becquerel: The disintegration of one radioactive atom per second.

Buried Transuranic Waste: Radioactive waste meeting the current definition of TRU waste, that was disposed by shallow land burial and other techniques at a number of sites owned and operated by the federal government in support of the nuclear weapons program from the 1940s through 1970. In 1970 the Atomic Energy Commission first identified TRU waste as a separate category of radioactive waste, and all TRU waste generated after 1970 has been segregated from low-level waste and placed in retrievable storage pending shipment to and disposal in an approved geologic repository. DOE has been evaluating retrieval of these materials, but no decision has been made.

Certified Waste: Containers of waste that meet the WIPP Waste Acceptance Criteria.

Code of Federal Regulations (CFR): 1) A codification of the general and permanent rules published in the *Federal Register* by the departments and agencies of the federal government. The CFR is divided into 50 titles that represent broad areas subject to federal regulation. It is issued quarterly and revised annually. 2) All federal regulations in force are published annually in codified form in the CFR.

Compliance Certification Application (CCA): DOE submits this application (Title 40 CFR Part 191, Compliance Certification Application for the Waste Isolation Pilot) to the EPA in order to request certification from the EPA for the WIPP facility.

Compressed Gas: Any material or mixture having in the container an absolute pressure exceeding 40 psia (pounds per square inch absolute) at 70 degrees F (49 CFR 173.300).

Consultation and Cooperation Agreement: An agreement that affirms the intent of the Secretary of Energy to consult and cooperate with the State of New Mexico with respect to state public health and safety concerns. “Agreement” refers to the July 1, 1981, Agreement for Consultation and Cooperation, as amended by the November 30, 1984, “First Modification,” the August 4, 1987, “Second Modification,” and the March 22, 1988, modification to the Working Agreement.

Contact-Handled Transuranic (CH-TRU) Waste:	Transuranic waste that has a measured radiation dose rate at the container surface of 200 millirem per hour or less and can be handled safely without special equipment when in closed containers.
Corrosives:	Aqueous materials with a pH less than or equal to 2 or greater than or equal to 12.5 (TRAMPAC, page 4–2 [EPA 40 CFR 261.22]).
Curies (Ci):	Unit of radioactivity. One curie equals 3.7×10^{10} nuclear transformations per second. This unit reflects the intensity of a radioactive source.
Data Quality Objectives (DQOs):	Qualitative and quantitative statements that clarify program technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
Defense Waste:	Radioactive waste from any activity performed in whole or in part in support of DOE atomic energy defense activities; excludes waste under purview of the USNRC or generated by the commercial nuclear power industry. It consists of nuclear waste derived mostly from the manufacturing of nuclear weapons, weapons-related research programs, the operation of naval reactors, and the decontamination of weapons production facilities.
Environmental Evaluation Group:	see *New Mexico Environmental Evaluation Group.*
Explosive:	Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion (i.e., with substantial instantaneous release of gas and heat (TRAMPAC, page 4–1 [49 CFR 173.50]).
Fingerprinting:	Tests typically performed at waste facilities regulated under the RCRA to ensure that incoming waste meets permit requirements. Fingerprinting is not allowed at WIPP.
G Value:	Measure of the amount of radiolytic decomposition caused by a specific amount of radiation. It is expressed in terms of how much of a material is produced or destroyed per unit of radiation absorbed, customarily as molecules produced or destroyed per 100 electron volts of energy absorbed. G values are often in the range of 0.01 to 2.
Gray (Gy):	Standard unit of absorbed dose of ionizing radiation. One gray is equivalent to one joule of energy absorbed per kilogram of matter. One gray is equal to 100 rad.
Half-Life:	The time for half of the atoms in a radioactive substance to disintegrate.
Half-PACT:	Payload container certified by the USNRC for road transportation of TRU waste to WIPP. Although the design is similar to TRUPACT-II (see below), HalfPACT is approximately 71/2 feet high and about 8 feet in diameter, and therefore lighter, than the TRUPACT-II. Each HalfPACT can carry up to seven 1,000-pound waste drums, and each WIPP transport truck can haul up to three HalfPACTs.
Hazardous Constituent:	Chemicals identified in Appendix VIII of 20 NMAC 4.1 Subpart II (40 CFR Part 261).

Hazardous Waste: Waste that, because of its quantity, concentration, physical, chemical, or infectious characteristics, may cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed (40 CFR 261.3). Hazardous wastes are listed in 20 NMAC 4.1 Subpart II (40 CFR Part 261) and/or exhibit one of the four characteristics (ignitability, corrosivity, reactivity, and toxicity) in 20 NMAC 4.1 Subpart II (40 CFR Part 261).

Hazardous Waste Codes: Numbers assigned to identify the EPA category of hazardous waste. Hazardous waste code assignment for remote-handled transuranic (RH TRU) waste ensures that only wastes that are permitted at WIPP are disposed of and ensures waste compatibility during the operational phase at WIPP.

Hazardous Waste Facility Permit (HWFP): Permit issued by NMED to allow disposal of DOE's contact-handled transuranic mixed waste (hazardous waste) in WIPP. The HWFP, issued on October 27 1999, addresses New Mexico regulations 20.4.1.500 and 20.4.1.900, see above.

Hazardous Waste Identification Number: A 12-character number used by state and federal governments to track handlers of hazardous waste and used oil. The first two characters are the postal code for the state (in Idaho, “ID”), the third character is either a letter or number, and the next nine characters are numerals. A complete identification number looks similar to ID0000123456.

Hazardous Waste Manifest: A set of forms, reports, and procedures designed to track hazardous waste from the time it leaves the generator facility at which it was produced until it reaches the off-site management facility that will store, treat, or dispose of it. The manifest contains information on the type and quantity of waste being transported, instructions for handling the waste, and signature lines for all parties involved in the process. EPA and DOT require a copy of the manifest prior to shipping hazardous waste off-site. Requirements to prepare and use the manifest are set forth in 40 CFR 262.

Headspace Gas: Gas within the free volume at the top of a payload container (between the container lid and the waste inside the container), such as a 55-gallon drum. The gas may be generated from biological, chemical, or radiolytic processes; this includes contributions from volatile organic compounds (VOCs) present in the waste.

Headspace Gas Analysis: Sampling using a gas-tight syringe to draw a headspace gas sample from beneath the drum or box lid. The sample is analyzed by gas chromatography and/or mass spectrometry for hydrogen, methane, and VOCs.

Land Withdrawal Act (LWA): Public Law 102–579 (as amended) withdraws the land at the WIPP site from “entry, appropriation, and disposal.” It transfers jurisdiction of the land from the Secretary of the Interior to the Secretary of Energy and reserves the land for activities associated with the development and operation of WIPP. It requires DOE to comply with EPA's radioactive waste standards and final disposal regulations and to conduct studies to analyze the impact of RH-TRU wastes on repository performance. It includes many other requirements and provisions pertaining to the protection of public health and the environment. The LWA was signed into law on October 30, 1992.

Manifest: see *Hazardous Waste Manifest.*

Mixed Waste: Toxic or hazardous waste contaminated with radioactive material regulated under the Atomic Energy Act and hazardous material regulated under the Resource Conservation and Recovery Act as identified in 40 CFR 261, Subparts C and D.

National TRU Waste Management Program: A DOE system-wide approach to the management and disposal of TRU waste stored and generated throughout the DOE weapons complex. DOE's Carlsbad Field Office manages this program. Information on the program is available at: <http://www.wipp.ws>.

New Mexico Environmental Evaluation Group (EEG): The New Mexico Environmental Evaluation Group conducts an independent technical evaluation of the operations of the WIPP to ensure the protection of public health and safety and of the environment of New Mexico. The EEG has been serving New Mexico in this capacity since 1978. Public Law 100–456 articulates EEG's role and responsibilities relating to WIPP.

New Mexico Hazardous Waste Act (HWA): New Mexico legislation that establishes the state's hazardous waste management program.

Newly Generated TRU Waste: DOE term for waste generated after the development, approval, and implementation of the TRU waste characterization program that meets requirements outlined in the TRU waste characterization Quality Assurance Program Plan. Part of the inventory might not have been generated yet (see Section 2.1).

Nondestructive Assay (NDA): NDA is a general term for a number of techniques, such as gamma spectroscopy and passive or active neutron measurement. These techniques provide information on the radionuclide content of waste and sometimes on its spatial distribution inside containers.

Nondestructive Examination (NDE): NDE is a general term for a number of techniques, such as radiography or computer tomography. Radiography is a non destructive, qualitative and semi-quantitative technique that involves X-ray scanning of waste containers to identify and verify their contents. Because of the shielding associated with RH-TRU waste, computer tomography, which involves several sources to produce a three-dimensional image, may be required rather than the more commonly used radiography.

Overpack: A container put around another container. In WIPP, overpacks would be used on damaged or otherwise contaminated drums, boxes, and canisters that it would not be practical to decontaminate.

Packaging: The assembly of components necessary to ensure compliance with packaging requirements. It may consist of one or more receptacles, absorbent material, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks.

Payload Container: In this report, the term refers to containers, such as 55-gallon drums, standard waste boxes, or ten drums overpack, that may be placed within the inner containment vessel of a transportation package, such as TRUPACT-II and HalfPACT, and to its requirements, such as package configuration, weight, heat generation, material content (e.g., pressurized gases and liquids), and criticality limits.

Performance Assessment: A quantitative assessment of the long-term performance of the WIPP repository. The performance assessment organizes information relevant to long-term (i.e., over a 10,000-year period) repository behavior by assessing the probabilities and consequences of major scenarios by which radionuclides can be released to the environment surrounding the WIPP site. Important scenarios include those due to human activities, whether deliberate or unintentional, that might occur near the WIPP site and potentially compromise the integrity of the repository.

Process Knowledge: Information about the characteristics of a waste gathered during the process that generated the waste.

Pyrophoric Material: Any material, other than one classed as an explosive, that under normal conditions is liable to cause fires through friction or through heat retained from manufacturing or processing, or that can be ignited readily and—when ignited—burns so vigorously and persistently as to create a serious transportation, handling, or disposal hazard. Spontaneously combustible and water-reactive materials are included (TRAMPAC, p. 4–1 [10 CFR 61.2.]).

Quality Assurance: The planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily.

Quality Assurance Program Plan (QAPP): Document that describes the overall program plans and activities to meet a project's quality assurance goals.

Rad: Unit of absorbed dose. It represents 0.01 joule of energy absorbed per kilogram of matter. Rad and rem are important units with regards to WIPP because requirements are expressed in rem, a derivative, or rad.

Radioassay: Term used to define measurement methods for determining the radionuclide content of waste, it includes both nondestructive assay and destructive assay (e.g., radiochemistry).

Radiography: A nondestructive, nonintrusive radiographic examination technique that enables a qualitative (and in some cases quantitative) evaluation of the contents of a waste container. Radiography utilizes X-rays to inspect the contents of the waste container in real time. It is used to examine and verify the physical form of the waste for certain waste forms, identify individual waste components, and verify the absence of certain noncompliant items.

Radiological Survey: Measurements of radioactive contamination levels or dose rates associated with a site together with the appropriate documentation and data evaluation. When AK indicates that some containers may approach 1,000 rem per hour or that some containers exceed 100 rem per hour, then radiological surveys of each container may be required. Industry standard survey instruments can be used in this process and are required to discriminate at 100 rem per hour and 1,000 rem per hour.

RCRA: See Resource Conservation and Recovery Act.

Rem (Roentgen Equivalent Man): Unit of absorbed radiation dose used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. The equivalent dose (rem) is determined by multiplying the absorbed dose (rad) by a quality factor (Q) that accounts for different biological effects caused by different types of radiation. Dose requirements regarding WIPP are expressed in this unit.

Remote-Handled Transuranic (RH-TRU) Waste: Transuranic waste that has a measured radiation dose rate at the container surface of 200 mrem per hour or greater but not more than 1,000 rem per hour. This waste must be handled remotely (i.e., with machinery designed to shield the handler from radiation).

Resource Conservation and Recovery Act (RCRA): A Congressional act that established a system for tracking and regulating hazardous wastes from the time they are generated through disposal. The law requires that hazardous waste generators use safe and secure procedures in treating, handling, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent new uncontrolled hazardous waste sites. The law also regulates the disposal of solid waste that may not be considered hazardous. Note: 20 NMAC 4.1 and 40 CFR Parts 260–281 are the regulations for complying with RCRA with respect to hazardous waste and hazardous waste treatment, storage, and disposal facilities in New Mexico.

Retrievably Stored TRU Waste: Waste generated after 1970. In 1970 the Atomic Energy Commission (predecessor of DOE) first identified TRU waste as a separate category of radioactive waste. The same year, the commission determined that all TRU waste generated after 1970 must be segregated from low-level waste and placed in retrievable storage pending shipment to and disposal in an approved geologic repository. Federal facilities in Washington, Idaho, California, Colorado, New Mexico, Nevada, South Carolina, Ohio, Tennessee, and Illinois are currently storing TRU waste. See also Buried Transuranic Waste.

Roentgen: Unit used to measure a quantity called exposure. The roentgen is that quantity of X- or gamma radiation less than 3 MeV in energy that produces 1 electrostatic unit of charge (2.58×10^{-4} coulombs), in 1 kilogram of dry air at 0 degrees C and an atmospheric pressure of 760 mm Hg. Many radiation measuring instruments measure the roentgen (ionization) directly. It is a measure of the ionizations of the molecules in a mass of air.

Safety Analysis: A documented process with the following purposes: 1) to provide systematic identification of hazards within a given DOE operation; 2) to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards; and (3) to analyze and evaluate potential accidents and their associated risks.

Safety Analysis Report: see *WIPP Safety Analysis Report.*

Sievert: Unit of measurement of radiation dose equivalent. One sievert is the absorbed dose, expressed in gray, multiplied by a quality factor to account for different biological effects caused by different types of radiation.

Summary Category Group: Categorizes each waste stream based on its physical form to facilitate RCRA waste characterization and reflect the final waste forms acceptable for WIPP disposal. The waste summary categories are identified by the generators and are the following:

• *Homogeneous Solids* (S3000): Homogeneous solids, or solid process residues, are defined as solid materials, excluding soil, that do not meet the NMED criteria for classification as debris (20.4.1.800 NMAC [incorporating 40 CFR §268.2[g] and [h]]. Included in the series of solid process residues are inorganic process residues, inorganic sludges, salt waste, and pyrochemical salt waste. Other waste streams are included in this Summary Category Group based on the specific waste stream types and final waste form. This Summary Category Group is expected to contain toxic metals and spent solvents. This category includes wastes that are at least 50 percent by volume solid process residues.

• *Soils or Gravel* (S4000): This Summary Category Group includes waste streams that are at least 50 percent by volume soil or gravel. This Summary Category Group is expected to contain toxic metals. Soil and gravel are further categorized by the amount of debris included in the matrix.

• *Debris Wastes* (S5000): This Summary Category Group includes heterogeneous waste that is at least 50 percent by volume materials that meet the criteria specified in 20.4.1.800 NMAC (incorporating 40 CFR §268.2(g)). Debris means solid material exceeding a 2.36-inch (60-millimeter) particle size that is intended for disposal and that is a manufactured object, plant or animal matter, or a natural geologic material. Particles smaller than 2.36 inches in size may be considered debris if the debris is a manufactured object and if it is not a particle of homogeneous solids or soil or gravel.

Toxic Substances Control Act (TSCA): Act enacted by Congress in 1976 to give EPA the ability to track the 75,000 industrial chemicals currently produced or imported into the United States. EPA repeatedly screens these chemicals and can require reporting or testing of those that may pose an environmental or human health hazard. EPA can ban the manufacture and import of those chemicals that pose an unreasonable risk.

TRAMPAC: TRUPACT-II Authorized Methods for Payload Control. Implementation document for the USNRC TRUPACT-II certificate of compliance.

Transuranic Waste: Radioactive waste consisting of radionuclides with atomic numbers greater than 92 in excess of agreed limits on half-life and concentration. A more precise definition, in DOE Order 435.1– 1 (July 9, 1999), is waste that is not high-level waste "contaminated with alpha-emitting radionuclides of atomic number greater than 92 and half-lives greater than 20 years in concentrations greater than 100 nanocuries per gram." The regulatory definition excludes actinide elements with atomic numbers between 90 and 92 (most significantly, thorium and uranium isotopes), in agreement with the literal meaning of "transuranic." However, common usage of "transuranic waste" is often understood to include all actinides.

TRUPACT-II: Transportation package certified by the U.S. Nuclear Regulatory Commission for road transportation of CH-TRU waste to WIPP. The acronym stands for Transuranic Packaging Transporter-II. The main components are two stainless steel containment vessels, one inside the other. A vacuum is drawn in between containment vessels. To prevent radioactive releases from the transportation package, the vessels are not vented. Up to fourteen 55-gallon drums or two standard waste boxes fit into the TRUPACT-II. The drums are banded together in groups of seven and stacked two high in the waste payload. The dimensions of the TRUPACT-II are 10 feet high by 8 feet in diameter. The maximum gross shipping weight of the TRUPACT-II is 19,265 pounds. Up to three TRUPACT-II transportation packages can be carried on a specially designed flatbed truck.

Type A Packages: Transportation containers that meet guidelines for certification in 49 CFR 173. These guidelines are less restrictive than those for Type B packages (see below). Examples of Type A packages are 55-gallon drums, standard waste boxes, and ten-drum overpacks, that have been previously determined to meet the applicable performance requirements for Type A packages.

Type B Packages: Transportation containers that meet stringent guidelines for certification designed to ensure that the packages will not release their contents under normal transportation conditions or various accident scenarios (10 CFR 71). Examples of Type B packages are TRUPACT-II and Half-PACT transportation packages.

Visual Examination (VE): Process consisting of physically examining TRU waste by opening the container and handling the waste. Visual examination can be performed in a glovebox.

Volatile Organic Compounds (VOCs): RCRA-regulated organic compounds that readily pass into the vapor state and are present in transuranic mixed waste.

Waste Acceptance Criteria (WAC): Set of conditions established for permitting transuranic wastes to be packaged, shipped, managed, and disposed of at the WIPP. The WAC constrain the physical, chemical, and radiological properties of TRU waste and its packaging as determined by WIPP's authorization basis requirements. TRU waste will not be approved for shipment to and disposal at the WIPP until it has been certified as meeting the WAC. Waste Acceptance Criteria ensure that CH-TRU waste is managed and disposed of in a manner that protects human health and safety and the environment.

Waste Analysis Plan (WAP): Part of the Hazardous Waste Facility Permit (HWFP) describing the procedures that will be carried out at a facility to obtain chemical and physical analysis of each waste managed so that all information will be known to treat, store, or dispose of the waste in accordance with 40 CFR 264.13.

Waste Characterization: Sampling, monitoring, and analysis activities to determine the nature of the waste.

Waste Matrix Code: Code assigned by the TRU waste generator or storage sites to categorize mixed and some non-mixed waste streams in the DOE system into a series of five-digit alphanumeric codes (e.g., S5400; Heterogeneous Debris) that represent different physical or chemical matrices. These codes were developed by DOE in response to the Federal Facility Compliance Act of 1992.

Waste Profile Form: Paper form that the waste generator must complete to identify and document properly the characterization of any solid, liquid, hazardous, radioactive, or mixed waste. The Waste Profile Form must provide a complete and concise description of the waste, including details of the generating process. The Waste Profile Form process provides generators with guidance for determining the waste's physical, chemical, and radiological characteristics with sufficient accuracy to allow proper segregation, treatment, and disposal according to the final treatment or disposal facility's Waste Acc.

Waste Stream: Waste material generated from a single process or activity or as multiple containers with similar physical, chemical, or radiological characteristics. In the WIPP Certificate of Compliance certification application, DOE identified 569 waste streams, while EPA sorted WIPP waste inventory by volume in 10 classes. The 11 NMED types of waste streams, called Waste Matrix Code Groups, are the following: solidified inorganics, solidified organics, salt waste, soils, lead/cadmium metals, inorganic nonmetal waste, combustible waste, graphite, filters, heterogeneous debris waste, and uncategorized metal (HWFP, 2003; Attachment B, page B-2). The 10 EPA categories are the following: uncategorized metals, heterogeneous waste, solidified inorganic waste, combustibles, soils, filters, graphite, lead or cadmium metal waste, salt waste, and solidified organic materials (DOE-TWBIR, 1996; Table 1, pages B2–5 through B2–19).

WIPP Safety Analysis Report (SAR): Document representing a statement and commitment by DOE that WIPP can be operated safely and at acceptable risk. This document summarizes the safety analyses to ensure the safety of workers, the public, and the environment from the hazards posed by WIPP waste handling and emplacement operations during the disposal phase and hazards associated with the decommissioning and decontamination phase. The WIPP SAR is prepared: 1) to satisfy the commitments in the Working Agreement for Consultation and Cooperation between the State of New Mexico and the U.S. Department of Energy; and 2) to ensure compliance with DOE's 10 CFR 830 about nuclear safety management.

WIPP Waste Information System: Database that contains information developed during the characterization process used to verify that the waste meets WIPP Waste Acceptance Criteria and the requirements in the HWFP.

Acronyms

AK	Acceptable Knowledge
ALARA	as low as reasonably achievable
CAB	Citizen Advisory Board
CBFO	Carlsbad Field Office
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CH-TRU	Contact-Handled Transuranic
DAC	drum age criterion
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objective
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
FGE	fissile gram equivalent
HSG	headspace gas
HWA	Hazardous Waste Act (New Mexico)
HWFP	Hazardous Waste Facility Permit
INEEL	Idaho National Engineering and Environmental Laboratory
LANL	Los Alamos National Laboratory
LDR	Land Disposal Restriction
LWA	Land Withdrawal Act

NDA	nondestructive assay
NDE	nondestructive examination
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NRC	National Research Council
OASIS	oil and solvent immobilization system
ppbv	parts per billion by volume
psia	pounds per square inch, absolute
QAO	Quality Assurance Objective
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RCT	radiation control technician
RFETS	Rocky Flats Environmental Technology Site
RH-TRU	Remote-Handled Transuranic
RTR	real-time radiography
SAR	Safety Analysis Report
SARP	Safety Analysis Report for Packaging
SRS	Savannah River Site
SWB	standard waste box
TDOP	ten-drum overpack
TRAMPAC	TRUPACT-II Authorized Methods of Payload Control
TRU	transuranic
TRUPACT	Transuranic Packaging Transporter
TSCA	Toxic Substances Control Act
USNRC	U.S. Nuclear Regulatory Commission
VE	visual examination

VOC	volatile organic compound
WAC	Waste Acceptance Criteria
WAP	Waste Analysis Plan
WGA	Western Governors Association
WH	waste handler
WIPP	Waste Isolation Pilot Plant
WSDF	Waste Stream Disposal Form