Chapter 2

Managing Transuranic Waste at the DOE Nuclear Weapons Complex

Contents

Box

Figures

Tables

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SUMMARY

Overview

It has been only 50 years since elements heavier than uranium-hence, the term Transuranic-were created. These elements do not occur in nature and were first produced in nuclear reactors as part of the World War II effort by the United States to develop the atomic bomb. An isotope of one of these elements, plutonium-239, has physical and nuclear properties that make it a desirable material for atomic weapons-only a few kilograms or tens of kilograms are required. Plutonium was the explosive material in the bomb dropped on Nagasaki. It is found in the "triggers" of tens of thousands of modern thermonuclear weapons in the arsenals of the United States and the Soviet Union. Whereas in the early 1940s, scientists working on the wartime Manhattan Project struggled to produce microgram quantities of plutonium-239, tons of it exist today.

Threats to human health from plutonium and other Transuranics do not arise solely from the possibility of their use in a thermonuclear conflict. Most Transuranic radionuclides decay by emitting helium nuclei—that is, alpha particles, a heavily ionizing form of matter. These alpha particles make plutonium toxic to humans in very small quantities when inhaled or ingested. Furthermore, some transuranic radionuclides are very long-lived and tend to persist rather than decay rapidly to other nuclides. A principal concern is plutonium-239, which has a half-life of 24,400 years; this means that half of the plutonium-239 in existence in 1990 will still exist in the year 26,390.

Plutonium-239 is produced via capture of neutrons by uranium-238 in nuclear reactors. This process goes on continually in commercial nuclear power reactors, as it did in the Hanford reactors for weapons production purposes during and after World War II. While in the U.S. commercial sector, almost all of the plutonium is contained within the solid structure of spent fuel elements removed from reactors, in the defense sector, plutonium is spread more widely in the environment because fuel elements and targets have been reprocessed, by using aqueous and organic liquids, to unlock and separate the plutonium for recovery and incorporation into weapons. Reprocessing has resulted in , contamination by plutonium of soil and sediments in the vicinity of certain sites in the Nuclear Weapons Complex. In addition, ,contamination of workers and workplaces from various plutonium handling and machining operations is a constant concern. One example of this is the report in 1990 that enough plutonium had accumulated in the ducts at the Department of Energy Rocky Flats Plant to fuel several nuclear weapons.

Transuranic (TRU) waste arises in the U.S. defense program primarily as a consequence of reprocessing plutonium-bearing fuel and irradiated targets, and from operations required to prepare the recovered plutonium for weapons use. TRU waste includes TRU metal scraps as well as glassware, process equipment, soil, laboratory waste, ion-exchange resins, clothing, filters, glove boxes, and paper products contaminated with TRU materials.

Until 1970, TRU waste was handled in a reamer similar to low-level waste (LLW): it was dumped into trenches or pits and covered over or buried; such waste is referred to as *buried TRU waste.* Pre-1970 practices have resulted in great uncertainty in the estimates and location of buried TRU waste and TRU-contaminated, soil. Subsequently, in accordance with a 1970 Atomic Energy Commission (AEC) decision, TRU waste was stored, usually in metal drums, in a manner to permit easy recovery and treatment, because of the growing realization that long-lived radionuclides such as plutonium-239 require more careful handling, storage, and long-term disposal than previously recognized; such waste is referred to as ***retrievable stored TRU waste. In*** general, the Department of Energy (DOE) views retrievable stored and yet-to-be-generated waste as a *waste management* problem, whereas buried waste is an ***environmental restoration*** problem; the two may require different technological, evaluative, and administrative approaches. Since the mid-1970s, plans for long-term disposal of TRU waste have centered upon the availability of a deep geologic repository, paralleling earlier thinking about disposal of high-level waste (HLW).

DOE's policy is that retrievable stored and yet-to-be-generated TRU waste will be disposed of in a geologic repository. The Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, was authorized by Congress in 1980 to serve as a research and development facility for disposal of such TRU waste in bedded salt. Upon completion of the test phase, WIPP might then serve as the first deep geologic repository for defense TRU waste. WIPP has now been built. To date, no waste packages have been placed in WIPP. A positive decision by Secretary of Energy James D. Watkins on DOE's readiness to proceed with the experimental phase was made in June 1990. The earliest date for disposal of TRU waste in the WIPP facility on a regular, operational basis is 1995. Other scenarios foresee WIPP opening much later.

Data and Projections

DOE collects information on various waste types in its Integrated Data Base (IDB), which is updated annually. According to the 1989 IDB (77), both retrievable stored and buried TRU waste are distributed over six sites: the Idaho National Engineering Laboratory (INEL) has 61 percent of the retrievable stored waste, and Hanford has 57 percent of the buried waste by volume. The volume of buried TRU waste is estimated to be three times that of retrievable stored TRU waste.[1] A seventh site, the Rocky Flats Plant, also has been storing TRU waste since late 1989 when the State of Idaho refused to accept further shipments. Most of the stored TRU waste by volume is ***contact-handled;*** that is, its radioactivity is sufficiently low that it is considered safe for workers to manipulate the drums. Smaller volumes of TRU waste at Oak Ridge and other sites have radioactivity levels sufficiently high, due to fission products mixed with the waste, to require that waste packages be handled remotely—hence, the term ***remote-handled*** waste.

The 1989 IDB (77) projects a large increase in radioactivity associated with total stored TRU waste by the year 2013, growing to 3.5 times the 1988 value (74).[2] Much of the growth appears to be associated with activities at the Savannah River Plant. The scaledown in growth indicated by the projections in the 1988 and 1989 IDBs could reflect some downward adjustment in weapons material requirements due to the improved arms control outlook. Nevertheless, existing projections indicate a growing burden of TRU waste to be managed over the next 25 years.

The Definition of TRU Waste

Transuranic (TRU) waste is defined as waste contaminated with alpha-emitting transuranium radionuclides with half-lives of more than 20 years and concentrations higher than 100 nanocuries per gram. This limit was raised from 10 nanocuries per gram in 1984. It permits DOE to reclassify and dispose of some of what used to be TRU waste as LLW. However, regardless of definition, the waste must meet appropriate disposal standards. At present, Environmental Protection Agency (EPA) standards for disposing of plutonium waste are either nonexistent or in need of review, and important elements of EPA radiation protection standards for disposal of TRU waste also need to be reissued.

Buried Transuranic Waste

Characterization of, and strategies for, handling buried TRU waste or remediating TRU-contaminated soil are in the very early stages. Thus, knowledge of buried waste sites and soil contamination is far from complete. A National Academy of Sciences panel is monitoring efforts by DOE and its contractor, EG&G-Idaho, to determine how to deal with buried TRU waste at INEL. Among the issues under consideration are better delineation of waste migration; the risks and benefits associated with in situ treatment of waste versus digging it up and treating it; and sites for disposal of the waste, if and when it is retrieved. Remediation of the Subsurface Disposal Area (SDA) at INEL where buried TRU waste is located has been governed by a Consent Order and Compliance Agreement (COCA), based on the Resource Conservation and Recovery Act[3] (RCRA), involving EPA Region X, DOE, and the

[1] IDB estimates of buried TRU waste are subject to considerable uncertainty. Stored TRU waste estimates should be somewhat more reliable, although large variations occur from year to year. In general, the IDB does not show ranges of estimates to provide some measure of their uncertainty.

[2] A similar projection made with data from the 1988 IDB shows a growth to almost eight times the 1987 value. However, the most recent projection in the 1990 IDB indicates a growth by the year 2013 to only 1.9 times the 1989 value.

[3] Pub. L. No. 94-580, 90 Stat. 2795 (1976) (codified as amended at 42 U.S.C. 6901-07 (1982); 42 U.S.C. 6911-16, 6921-31, 6941-49, 6951.54, 6961-64,6971-79,6981-86 (1982)); amended by Solid Waste Disposal Act Amendments of 1980, Pub. L. No. 96-482,94 Stat. 2334 (1980) (codified at 42 U.S.C. 6901-91 (i) (1982)); Hazardous and Solid Waste Amendments of 1984, Pub. L. No. 98-616,98 Stat. 3221 (codified at 42 U.S.C. 6924 (1984)).

U.S. Geological Survey (USGS). An interagency agreement based on the Comprehensive Environmental Response, Compensation, and Liability Act[4] (CERCLA) addressing remediation of nonoperating disposal sites is awaiting Secretary Watkins' approval. Studies of alternative remediation techniques will undoubtedly continue for some time.

Some technologies used for cleanup of buried TRU waste sites could prove to be similar to those used for LLW sites. However, EPA disposal requirements equate TRU waste with HLW and both are currently slated for disposal in deep geologic repositories. A major effort is still required to sort out which technology will be useful and cost-effective for each waste situation, both for remediation of buried TRU waste sites and for treatment of stored TRU waste. The presence of hazardous components mixed with radioactive materials must also be taken into account.

In situ vitrification (ISV) is being investigated for use in immobilizing radionuclides and hazardous materials in contaminated soil or in buried drums. Electrodes placed in the soil melt and then harden the soil and its contents into a glasslike substance. This technology, while promising, also has limitations, including high operating (energy) costs, applicability to relatively shallow soil depth and dry soil, and possible worker hazards from strong electric fields and from generated vapors. Economic analyses of the projected costs of ISV as a function of the amount and nature of material to be immobilized are necessary. The first full-scale ISV test has been underway in a waste crib at Hanford that is a high-priority cleanup site. Demonstration tests are also being carried out at INEL.

One problem being studied at INEL in connection with buried TRU waste is the development of plumes of volatile organic compounds beneath the surface that might accelerate the migration of radionuclides to groundwater. Efforts are underway to characterize the carbon tetrachloride plume under the SDA and in the vadose zone. A vapor vacuum extraction process for removing organic vapor from subsurface areas is also being tested.

Storage and Treatment of Retrievable Stored Transuranic Waste

Currently, stored TRU waste is usually found in 55-gallon drums placed on concrete or asphalt pads, awaiting assay, treatment, and certification for shipment to and disposal at the WIPP. The waste in these drums is soluble, respirable, and not generally fried in an immobilized matrix. The drums were designed for a lifetime of 20 years, and some drums have held TRU waste for that period. Six of eight drums retrieved from a pad at INEL in late 1989 had rust holes up to 4 inches in diameter; no leakage is reported to have occurred because the waste was contained in internal polyethylene bags. The duration of waste drum storage for TRU waste mixed with contaminants considered hazardous under RCRA is also limited by EPA land disposal restrictions.

According to the 1989 Five-Year Plan, six new DOE facilities were scheduled to begin operation during FY 1992-99 for processing, treating, and certifying retrievable stored or newly generated TRU waste for shipment to WIPP. Among the technologies to be used in one or more of these facilities are shredding, incineration, compaction, and immobilization in grout or concrete. The first facility that was scheduled to begin operation, the Processing Experimental Pilot Plant (PREPP) at INEL, has encountered both technical and regulatory problems and its future is uncertain. PREPP incorporates rotary kiln incineration and an elaborate off-gas cleanup system to reduce radioactive and hazardous gas releases. Although incineration as a treatment technology has received considerable attention from EPA, it has generally encountered considerable public opposition.

A short-term problem facing DOE is what to do about the mixed TRU waste at the Rocky Flats Plant. The State of Idaho stopped accepting Rocky Flats waste in late 1989, and Colorado, using its RCRA authority set a limit of 1,601 cubic yards on the amount of mixed TRU waste that can be stored. That limit could be exceeded in 1991 or 1992. A further problem involves a Federal District judge's April 1990 ruling reclassifying some Rocky Flats residues as waste. DOE and State officials have been negotiating an Order of Consent to reflect the court ruling; the conditions of the order will then be

[4]Pub. L. No. 96-510, 94 Stat. 2'767 (1980) (codified as amended in scattered sections of the I.R.C. and 33, 42, and 49 U. S.C.). Any reference to CERCLA made throughout this paper should be construed as a reference to the 1980 statute, as amended by the 1986 Superfund Amendments and Reauthorization Act and codified at 42 U. S.C.A. %01-11050 (West 1983 and Supp. 1990).

incorporated as part of the permit application for the facility. DOE has also submitted a permit request seeking approval for the operation of a volume reduction unit (or supercompactor) to compact certain existing wastes and improve current capacity.[5]

The Waste Isolation Pilot Plant

As of early 1991, the experimental phase at WIPP still had not begun, and some obstacles remained to be overcome. In 1990 legislation was proposed in Congress to withdraw land from the public domain for WIPP use but it did not pass. The legislative debate on land withdrawal provided an opportunity for those with concerns about WIPP to express them and to attempt to build into the legislation certain conditions to which DOE must adhere. Among the concerns expressed were the need for compensation to the State of New Mexico in the form of funds for highway construction to bypass certain areas; limitation of the amount of waste that can be placed in WIPP until DOE can demonstrate that EPA's disposal and no-migration standards for mixed TRU waste can be met; resolution of certain technical and safety issues related to the experiments; and debate about the merits of providing independent, non-DOE regulation of the WIPP facility. However, DOE bypassed the legislative route and land withdrawal was accomplished administratively in early 1991, even though the Department had stated that it would prefer not to pursue this course of action.

In 1987, EPA standards for geologic disposal were remanded by the court and may not be in effect when the WIPP experimental phase begins. If so, DOE might have to remove the waste at some future date either to comply with new standards when they are issued or because tests fail to support a determination that the standards can be met. Alternatively, DOE could defer moving waste to WIPP, but then it would continue to be stored on sites in States where it is not welcome. The General Accounting Office (GAO) has called for more contingency planning on DOE's part for waste storage. GAO has also suggested that Congress consider placing some restrictive requirements, such as limiting the amount of waste that can be emplaced prior to issuance of EPA disposal standards, in any legislation that may be proposed to withdraw public lands for the WIPP repository. The State of New Mexico has agreed to DOE conforming, with the disposal standards vacated by the courts until new standards are issued.

The generation of gas in drums containing TRU waste, in the form now planned for placement in WIPP, is a problem that must be addressed. Some have used currently available information on gas generation rates to predict that within 50 to 100 years after disposal in WIPP, the buildup of gas due to corrosion of the carbon steel drums and to radiolytic and biological degradation of organic materials could reach pressures at which salt might be fractured or pushed back and radioactive or hazardous materials might escape from the repository. Although DOE and its contractors are studying the problem and hope to obtain additional information from the initial tests at WIPP to supplement earlier information, some experts feel that modifying the current waste form to either reduce or eliminate gas generation will be necessary. By treating the waste with methods ranging from compaction to immobilization, to reduce or eliminate gas generation, uncertainty concerning long-term repository behavior and the vulnerability of the repository to both undisturbed and human intrusion scenarios could be lessened. However, treating TRU waste, particularly by methods that should be most effective in eliminating gas generation (i.e., incineration or vitrification) would require a substantial increase in funding as well significant changes in DOE waste management plans and facilities, would cause commensurate delays, and could increase worker radiation exposures.

Interested parties disagree on the value of the WIPP experimental phase as it is presently defined. Questions have arisen as to whether certain experiments will provide the information required to determine whether EPA disposal standards can be met, or whether some experiments might be performed more expeditiously outside of WIPP. In addition, although a task force created by DOE is studying alternative forms, as of late 1990, the initial experiments planned for WIPP did not appear to include certain alternative waste forms that would generate less gas than the existing preferred form. WIPP was authorized by Congress as a research and development facility to demonstrate safe disposal of TRU waste; yet, as it is now constituted, the program proposed by DOE does not appear to have convinced its critics that all important concerns have or will be addressed.

[5]F. Dowsett, Colorado Department of Health, personal communication, Jan. 4, 1991.

Standards, Regulations, and Oversight

EPA disposal standards represent the primary line of defense for public health and safety against radioactivity from TRU waste. These standards, promulgated in 1985, are being reformulated because they were vacated in June 1987 following a court challenge. New standards were expected to be proposed by EPA in late 1990 (they were not) and finalized by 1992. Concern has been expressed about DOE's ability to meet these standards without changing the waste form or using engineered barriers, particularly under human intrusion scenarios. DOE does not expect to be in a position to demonstrate compliance until the performance assessment is completed in 1995; it views the WIPP experimental phase as not requiring such compliance because the waste for the experiments will be retrievable. EPA concurs with this position.[6] Efforts to weaken the standards have been opposed by the Environmental Evaluation Group (EEG), the federally mandated WIPP oversight group associated with the State of New Mexico.

Independent technical oversight of WIPP by EEG is valuable to the process of developing a viable disposal facility and enhances DOE's credibility. Although other oversight mechanisms utilized by DOE provide useful inputs, EEG's full-time, long-term presence, permanent staff and consistent resources are unique elements that contribute to its effectiveness. Also of importance is EEG's ability to remain independent of DOE, even though its funding comes from the Department,

Much TRU waste is mixed (radioactive and hazardous) waste to which RCRA regulations apply. DOE has requested a no-migration variance for waste to be placed in WIPP, arguing that hazardous waste will not move off-site. In April 1990, EPA proposed to grant DOE's request for the experimental phase only, with a decision on the operational phase to be made later. EPA approval of the WIPP no-migration petition for the test phase followed on November 1, 1990, subject to several conditions, including testing of gases from each of the waste drums to be placed in WIPP during the test phase.

With regard to mixed TRU waste stored at DOE facilities, storage or disposal of such waste is generally prohibited by EPA under land ban restrictions unless the waste has been treated in an EPA-approved manner. However, in light of the limited capacity available nationwide to treat mixed TRU waste, EPA issued a 2-year variance on June 1, 1990, to provide sufficient time for building the capacity required to treat the mixed waste generated and stored at facilities in the DOE Weapons Complex. As a result, DOE is not required to comply with the treatment and disposal requirements applicable to mixed waste under RCRA until 1992.

Research and Development, Waste Minimization, Transmutation

The DOE Applied Research, Development, Demonstration, Testing, and Evaluation Plan (47) singles out three specific areas for TRU (retrievable stored or newly generated) waste management: better waste treatment to meet WIPP certification requirements; disposal options for waste not certifiable for WIPP; and better characterization of RCRA components in waste for certification. The plan lists a number of technologies that might prove useful for the buried waste remediation effort but does not evaluate them. A process for doing so may be underway in connection with updates of the Five-Year Plan.

Minimizing waste from plutonium manufacturing and processing can reduce the amount and radioactivity of TRU waste. Among the opportunities for such minimization, according to DOE, are forming blanks closer to final size, improving machining precision, using robotics and automation in handling, and improving plutonium recovery by using fewer chemicals and producing less plutonium-bearing waste. However, to date, DOE is not very far along in the TRU waste minimization area. The most substantial TRU waste minimization has likely been a result of the shutdown of operations at Rocky Flats since late 1989.

Transmutation is believed by some to be an attractive concept for minimizing TRU waste.[7] It involves separating (partitioning) long-lived TRU and other radionuclides from the waste stream for recycling and subsequent conversion (transmutation) to shorter-lived radionuclides by nuclear reactions in a reactor or an accelerator, thereby reducing the time required for the radioactive wastes to decay

[6] This position is inconsistent with tbe parallel case of the Yucca Mountain, NV, HLW repository. There, the NRC requires demonstrated compliance with long-term disposal standards before construction can begin.

[7] The phrase actinide conversion is used by some to characterize this process.

Box 2-A—Definition of Transuranic Waste[1]

Transuranic (TRU) Waste is defined in Department of Energy (DOE) Order 5820.2A (58) as follows:

> Without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g at the time of assay. Heads of Field Elements can determine that other alpha contaminated wastes, peculiar to a specific field site, must be managed as transuranic waste.

DOE Order 5820.2A (58) also defines two subsets of packaged TRU waste as follows:

> *Remote-Handled Transuranic Waste.* "Packaged transuranic waste whose external dose rate exceeds 200 mrem per hour. Test specimens of fissionable material irradiated for research and development purposes only and not for the production of power or plutonium may be classified as remote-handled transuranic waste."

> *Contact-Handled Transuranic Waste.* "Packaged transuranic waste whose external surface dose rate does not exceed 200 mrem per hour."

[1]Ci/g = nanocuries per gram (1 nanocurie = 10^{-9} curies); mrem = millirem.

to acceptable levels after disposal. One reason given for continued finding of the Fast Flux Test Facility at Hanford is for just this purpose. However, transmutation is still in the research stage; it is not a part of recent DOE 5-year waste management operations plans, nor is it likely to prove useful for TRU waste management over the next 10 years. These are also significant obstacles to transmutation becoming a major factor in TRU waste management over the long-term.

Transuranic WASTE AT DEPARTMENT OF ENERGY SITES

Definition and Background

In the United States, TRU waste is largely unique to the defense program and arises primarily through reprocessing of plutonium-bearing fuel and irradiated targets, and from the many operations required to manufacture plutonium in the form and grade required for use in nuclear weapons.[8] Some TRU-contaminated waste is also generated by remedial action projects as well as by decommissioning and decontamination n activities. TRU waste includes metal, glassware, process equipment, tools, soil, laboratory waste, rubber gloves, ion-exchange resins, filters, clothing, rags, and paper products (55,77). Among the TRU waste forms are absorbed liquid or sludge, combustibles, dirt, gravel or asphalt, and concreted or cemented sludge. Much TRU waste is mixed waste, containing both radioactive and hazardous components. Box 2-A contains current definitions of TRU waste.

TRU waste clearly is managed much more carefully now than it was 20 years ago. Until that time, it had been handled in a fashion similar to LLW---dumped into trenches or pits and covered with earth. In 1970 the Federal Government began to store TRU waste for easy retrieval rather than burying it in pits and trenches (77). One reason for the earlier lack of rigor in handling certain forms of Transuranics might have been that the radioactivity associated with items such as contaminated clothing was not very large compared with the radioactivity associated with liquids from reprocessing plants.

According to table 2-1, the TRU radionuclide that is preferred as a nuclear weapons material, plutonium-239, has a half-life of 24,400 years. Plutonium-239 is toxic in very low concentrations, with the primary health threat coming from the inhalation of material that lodges in the lungs and emits heavily ionizing alpha particles that are readily absorbed and could produce carcinogenic effects. The staying power of the long-lived, radioactive Transuranics, coupled with their toxicity when inhaled or ingested, necessitates their careful handling, treatment, and disposal.

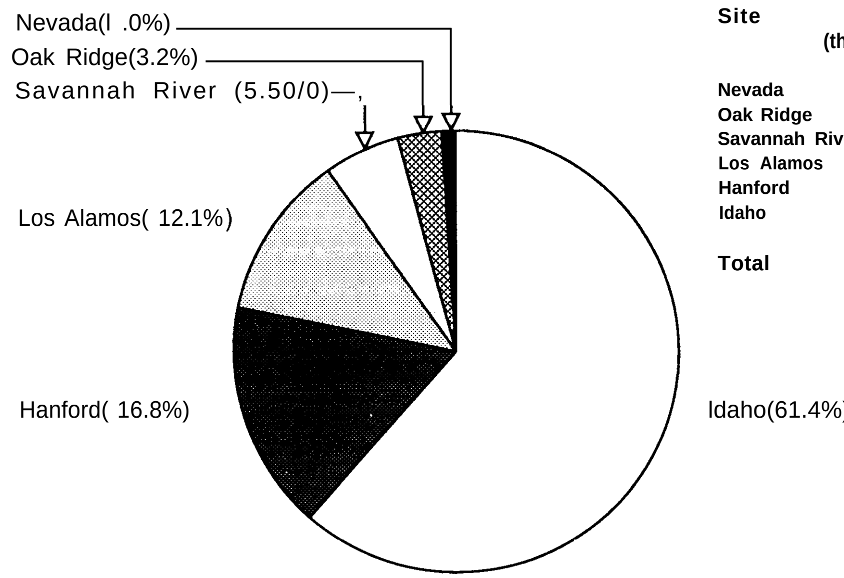
Table 2-l-Some Transuranic Radionuclides and Their Half-Lives

Element	Atomic weight	Half-life (years)
Neptunium	237	2.14×10^6
Plutonium	238	86
	239	24,400
	240	6,580
	241	13.2
	242	3.79×10^5
Americium	241	458
	243	7,950
Curium	244	17.6
	245	9,300

SOURCE: M. Benedict, T.H. Pigford, and H.W. Levi, *Nuclear Chemical Engineering,* 2d ed. (New York: McGraw-Hill, 1981), pp. 976-977.

[8]One exception to this statement is TRU waste produced during reprocessing of commercial reactor fuel at West Valley, NY, between 1966 and 1972.

Figure 2-l—Total Volume of Retrievable Stored DOE Transuranic Waste Through 1988



Site	Volume (thousand cubic meters)
Nevada	0.60
Oak Ridge	1.91
Savannah River	3.30
Los Alamos	7.19
Hanford	10,00
Idaho	36.70
Total	**59.50**

SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

In 1984, the level defining the lower concentration limit for TRU waste was increased from 10 to 100 nanocuries per gram. Waste that contains Transuranics below this level can be treated as LLW. The latter level was reportedly chosen ''because it is similar to the level of the naturally occurring TRU in ore' (17). Another consideration may have been the cost savings for treatment and disposal. In addition, new assay techniques permitted determining TRU concentrations down to the 100 but not the 10 nanocuries per gram level. Some issues concerning the definition of TRU waste are discussed later.

Amount and Distribution

Some Integrated Data Base Estimates

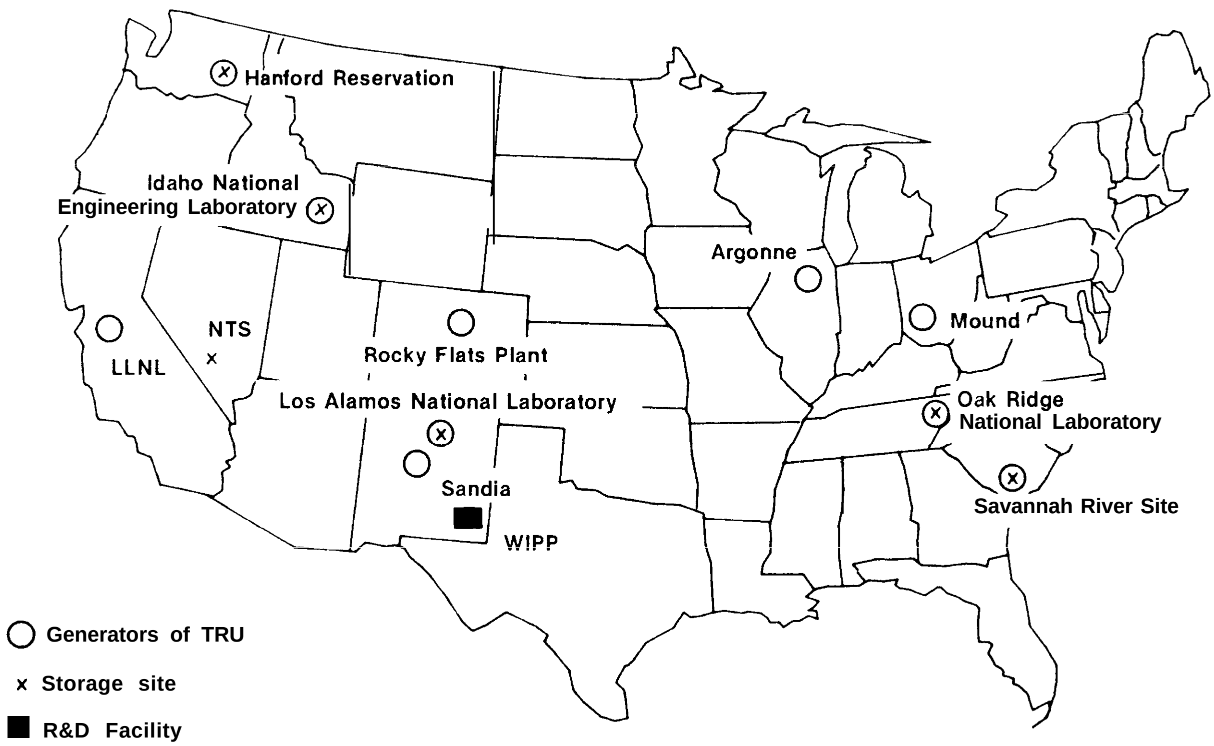
The 1989 DOE Integrated Data Base provides the following information on TRU waste at DOE weapons sites at the end of 1988. TRU waste radioactivity, estimated at 3.94 million curies, is about 0.34 percent that of defense HLW and about 30 percent of defense LLW (76). On the other hand, its volume, 251,000 cubic meters, is 65 percent that of HLW and 10 percent of LLW (76).

TRU waste is more widely distributed geographically than high-level waste. Figure 2-1 shows the total volume of *retrievable stored*[9] TRU waste through 1988 (78). This waste is spread over six sites, ranging from the Idaho National Engineering Laboratory (INEL) with 61 percent of the total to the Nevada Test Site with 1 percent of the total. The estimated volume of *buried* TRU waste is more than three times the volume of retrievable stored TRU waste (80). Buried TRU waste is also located at six sites, five of which contain retrievable stored TRU waste. Hanford has the largest share of buried TRU waste by volume (57 percent) followed by INEL (30 percent). The IDB estimates that the radioactivity of buried TRU waste is less than 2 percent that of retrievable stored TRU waste (83). However, buried waste estimates are subject to great uncertainty.

Figure 2-2 shows both points of origin and storage sites of DOE TRU waste. Although five sites are

[9]TRU waste is divided in the IDB into retrievable stored waste and buried waste. Estimates of the amounts of retrievable stored waste are likely to be the more accurate because some buried waste locations may not be known or characterized. No TRU waste was buried after 1978 (78). Presumably, buried waste volumes are educated guesses, aided in part by some historical inquiry and records. Less uncertainty is associated with the amounts of retrievable stored waste. In the past, DOE designated all waste that contained Transuranic materials as TRU waste, whether or not significant, separable amounts of LLW waste were also present. However, more recently, driven by limitations on storage of mixed waste at Rocky Flats, DOE has been increasing its use of nondestructive assay techniques to segregate TRU waste from LLW. Sampling efforts have led DOE to estimate that 38 percent of all stored waste originally categorized as TRU waste is in fact LLW, and TRU waste inventories have been lowered accordingly (80). Further changes can be expected.

Figure 2-2—Points of Origin and Storage Sites of DOE Transuranic Waste



SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

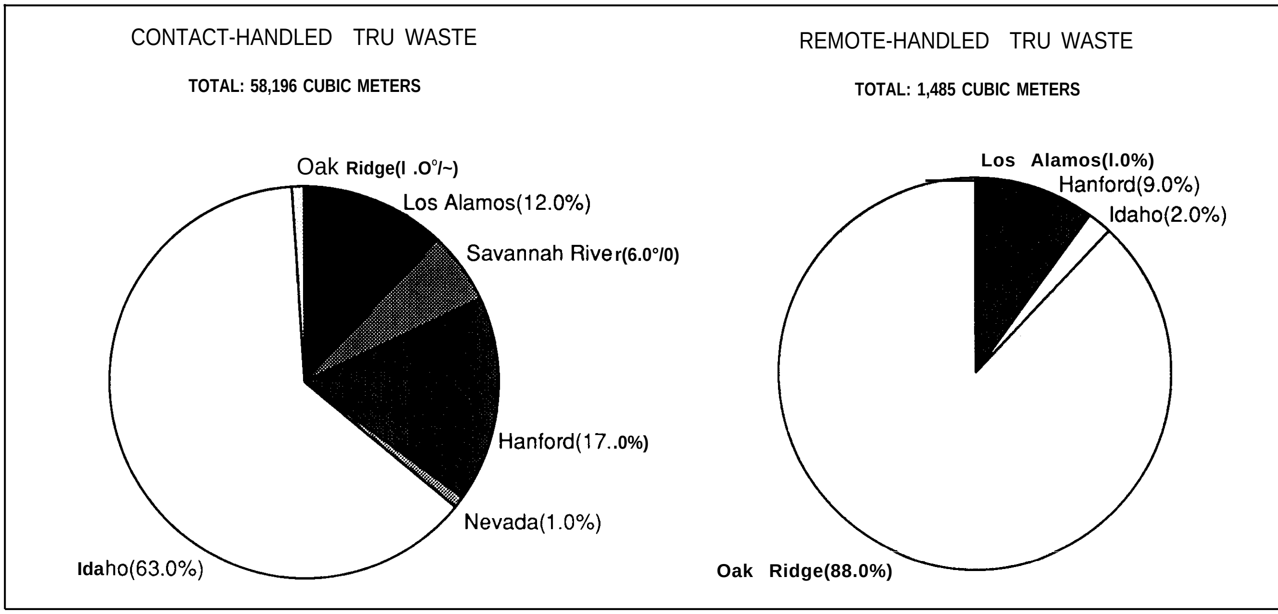
indicated as waste generators only, some interim storage of TRU waste is taking place at the Rocky Flats Plant as a result of a decision in September 1989 by the Governor of Idaho not to accept any more shipments of TRU waste from Rocky Flats. Other generator locations shown on figure 2-2 but not included in figure 2-1, also have TRU waste on-site.

Figure 2-3 shows the distribution among sites of contact-handled versus remote-handled TRU waste. According to table 3.5 of the 1989 IDB, 88 percent by volume (62 percent by radioactivity) of the "hotter,' remotely handled stored waste is at Oak Ridge National Laboratory (ORNL) (81). From that table, remote-handled stored waste can be estimated at 1.6 percent of the total volume (3.6 percent of the radioactivity) of stored TRU waste (81). In contrast to contact-handled TRU waste, which emits predominantly alpha radiation, remote-handled TRU waste has significant amounts of the more penetrating non-alpha radiation (garoma, beta, or neutrons). More than half (56.5 percent) of the total 1988 alpha radioactivity of retrievable stored, contact-handled waste is at Savannah River, some 653,000 curies. The alpha radioactivity at INEL, 73,000 curies, constitutes about 60 percent of all buried TRU alpha radioactivity (82).

Figure 2-4 shows total system inventories, projections, and characteristics of all buried and stored TRU waste as of 1988, projected in 5-year increments through the year 2013.[10] Several items should be noted: buried waste in 1988 is indicated as having

[10] The use of different estimating methods in the IDB leads to considerable difficulty in summarizing TRU waste inventory information. Values of radioactivity in figure 2-4 were calculated by using estimated isotopic compositions for TRU waste and a computer model. Volumes of stored waste are stated to be "certified TRU waste" and to exclude waste managed as LLW. On the other hand, values for figure 2-3 were derived from data provided by the field offices that include estimates of volume and alpha radioactivity for waste certified as TRU waste plus stored waste to be managed as LLW. Using figure 2-4 to compute the percentage of radioactivity associated with remote-handled waste gives results very different from figure 2-3.

Figure 2-3—Volume of Retrievable Stored Contact-Handled (CH) and Remote-Handled (RH) Transuranic Waste Accumulated Through 1988



SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

only 1.6 percent the radioactivity of total TRU waste,[11] although its volume is more than three times that of stored TRU waste; large annual increases in the radioactivity of stored, contact-handled waste are projected through the year 2013; there is a very large projected increase in the radioactivity of total stored waste to the year 2013, to more than *3.5* times the 1987 value. The last item is in marked contrast to the current projections of little or no change in total radioactivity of stored high-level waste over the same time period. (See ch. 1.)

Changes in Estimated Amounts

The 1989 IDB contains some major changes in TRU waste estimates (77). The value given there for the radioactivity of buried TRU is only 25 percent that given in the IDB for the previous year (74). This major reduction in radioactivity is due primarily to a drastic change in the reported radionuclide composition of Hanford buried waste from almost all plutonium-239 to almost all uranium.[12] The change may be indicative of uncertainties in the IDB.

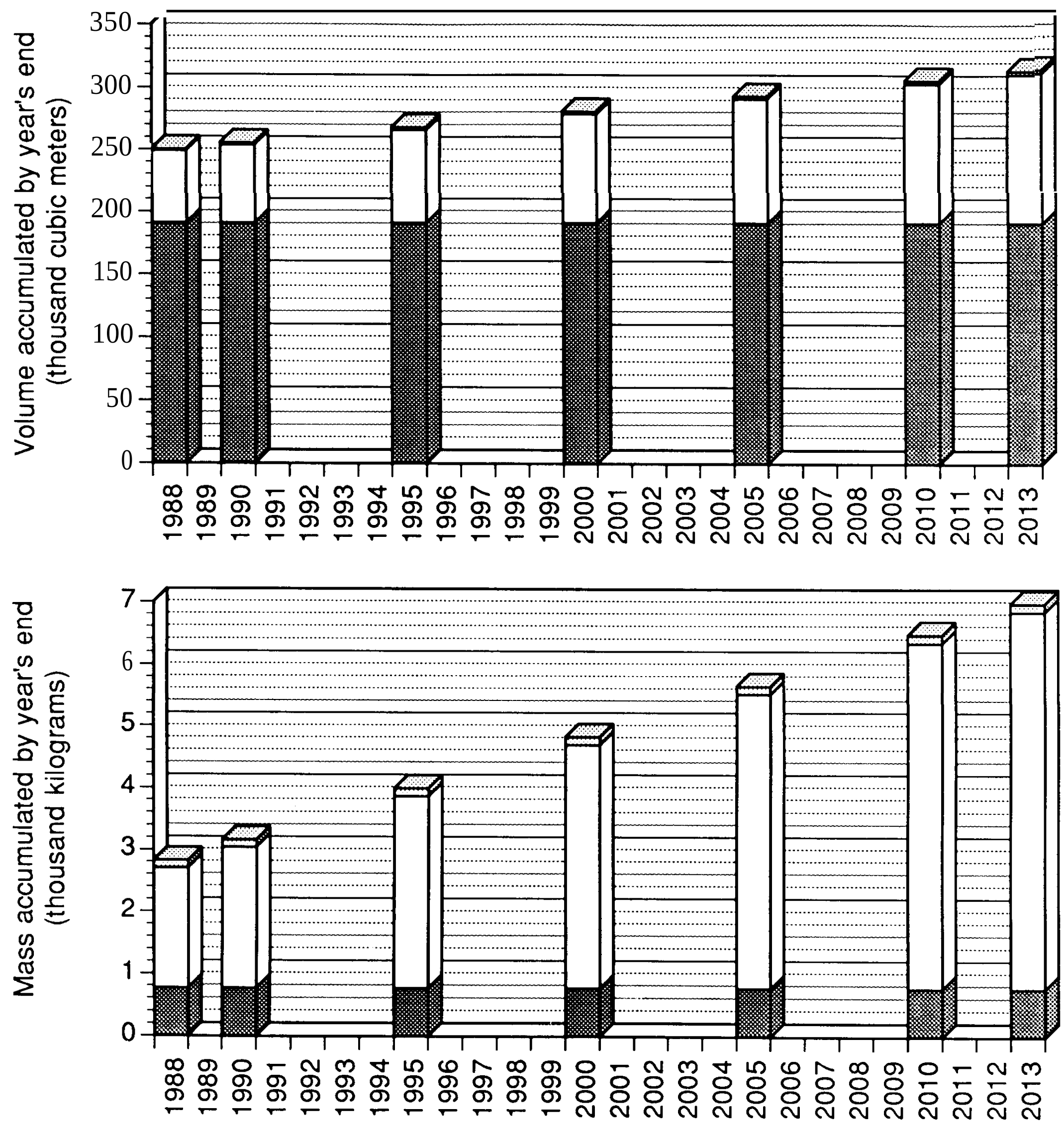
A highly significant change took place in estimates of TRU retrievable stored waste between the 1987 and 1988 IDB. Some 38 percent of what had been classified as TRU waste was reclassified as LLW. There were also some substantial upward revisions of estimates of the radioactivity of contact-handled TRU waste at Hanford and Savannah River, as well as a drop in the radioactivity of remote-handled waste at ORNL. By contrast with the relatively minor changes from year to year in HLW inventories, the large changes in TRU inventories appear to reflect greater uncertainties in these estimates.[13] The uncertainties are probably greater for buried waste, although information on stored

[11] It should be noted that radioactivity estimates of buried TRU waste are highly uncertain.

[12] Klein, J. A., Oak Ridge National Laboratory, personal communication Apr 16, 1990.

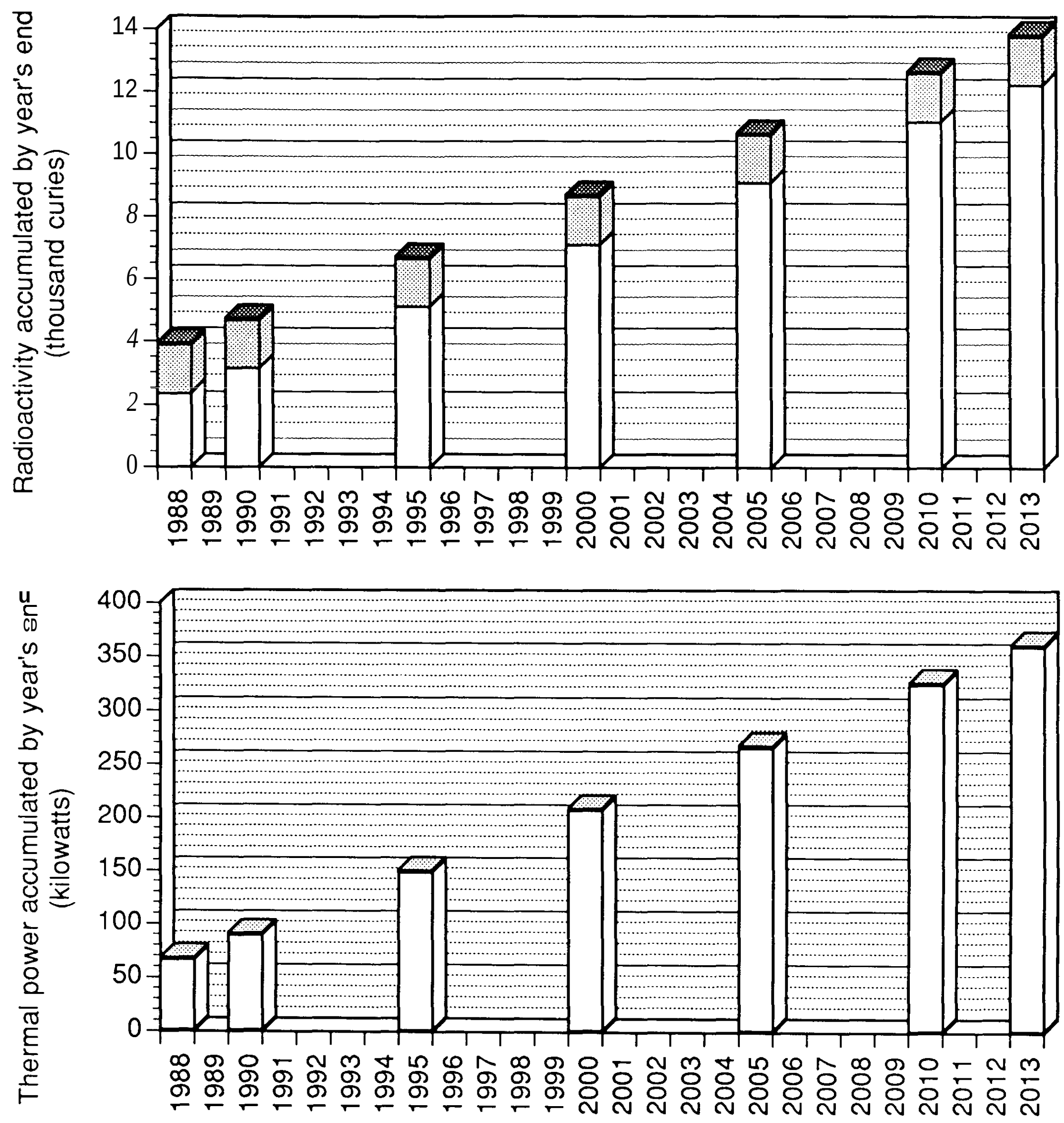
[13] This becomes particularly important in tracking the amount of waste scheduled to be shipped to the Waste Isolation Pilot Plant (WIPP). It has been pointed out that a tenfold reduction in the total radioactivity of remote-handled TRU waste destined for WIPP occurred from the final WIPP Environmental Impact Statement (EIS) to the supplementary EIS (23). Because this amount includes waste yet to be generated as well as stored waste, the reduction could be due to changes in the projected amount of waste to be generated, changes in the estimates of existing waste, or some combination of both. The IDB is of no help in sorting this out.

Figure 2-4—Total System Inventories, Projections, and Characteristics of All Buried and Stored DOE Transuranic Waste



Notes:
a. Annual rate is for the indicated Year only.
b. No TRU waste was buried after 1978.
c. All TRU waste is certified and excludes waste managed as LLW.
d. The destination of TRU waste after 2013 will not be defined until 2002.
e. Total mass does not include values for Hanford.

Figure 2-4—Total System Inventories, Projections, and Characteristics of All Buried and Stored DOE Transuranic Waste-Continued



Notes:
a. Annual rate is for the indicated year only.
b. No TRU waste was buried after 1978.
c. All TRU waste is certified and excludes waste managed as LLW.
d. The destination of TRU waste after 2013 will not be defined until 2002.
e. Total radioactivity and thermal power do not include values for Hanford.

KEY: CH==contact-handled; RH-remote-handied.

SOURCE: Adapted from U.S. Department of Energy, "integrated Data Base for 1989," DOE/RW-0006, November 1989.

Table 2-2—Inventories and Characteristics of Soil Contaminated With DOE Transuranic Waste Through 1988

Site	Volume (cubic meters)	Mass of TRU nuclides (kilograms)	TRU alpha radioactivity y (curies)
Hanford Plant	31,960	190.2	16,706
Idaho National Engineering Laboratory	56,000-156,000	a	a
Los Alamos	1,140	a	a
Mound Plant	300-1,000	0.009-0.029	150-526
Oak Ridge National Laboratory	13,000-61 ,000[b]	a	a
Savannah River Site	38,000	a	a
Total	140,400-289,100	a	a

[a]Reported as unknown.
[b]If soil containing TRU waste can be isolated from 1,600,000 cubic meters of soil containing TRU and LLW waste. Total also includes 1,000 cubic meters of contaminated soil around tanks.

SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

waste is also difficult to interpret. The stored waste appears to be undergoing systematic assay, which will result in reclassifying some TRU waste as LLW. In the meantime, attempts to utilize data in the IDB should be viewed with caution; the data lend themselves to manipulation because some waste may not have been identified and documented; in the past, different facilities have used different data gathering procedures. Some improvements have taken place in the IDB; hopefully, more will be forthcoming.

Table 2-2 provides a partial estimate of inventories and characteristics of soil contaminated, with DOE defense TRU waste through 1988, Only the radioactivity at Hanford and Mound are estimated, with the latter reporting a large range whereas Hanford provides a specific number estimate to five significant figures. A range of volumes is given for the Idaho National Engineering Laboratory (INEL) and the Oak Ridge National Laboratory (ORNL), indicating great uncertainty in the estimates; furthermore, at least for Oak Ridge, the volumes are predicated on being able to separate TRU waste from a much larger volume of soil containing both TRU and LLW. The values of volume and mass in table 2-2 are characterized as ''very difficult to accurately determine" (77).

Waste Management: Present and Planned

Major changes in the management of TRU waste are underway at DOE facilities. Prior to 1970, TRU waste was disposed of by shallow land burial and not distinguished from LLW. By the end of this century, DOE plans to begin to dispose of TRU waste by placement of "certified' packages in a deep geologic repository. The transition from pre-1970 to 21st century practices involves a complicated set of technical and regulatory developments.

Beginning. in 1970 (61), a policy was implemented that is characterized by monitored retrievable (interim) storage. For contact-handled TRU waste, the approach taken by DOE and its predecessor agencies was construction of large concrete or asphalt pads on which drums or boxes of waste could be stacked, protected with weatherproofing material, and, in some cases, periodically covered with earth. Sumps were provided for collecting any moisture present, and air sampling equipment measured humidity and radioactivity. Six of its operations offices are reported by DOE to manage such facilities: Albuquerque, NM; Richland, WA; Idaho; Nevada; Oak Ridge, TN; and Savannah River, GA. Also stored are relatively small quantities of remote-handled TRU waste under conditions that provide shielding from radiation. DOE asserts in the 1989 Five-Year Plan that no migration of radioactive or chemical contaminants, has occurred (61). The retrievable stored TRU waste packages were designed to last for at least 20 years (55); some of these packages are now 20 years old.

It is DOE's current policy that all stored or yet-to-be-generated TRU waste, both contact- and remote-handled, will be disposed of in a geologic repository. According to the 1989 Five-Year Plan, "the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, will be the disposal facility for TRU waste. A Waste Acceptance Criteria Certification Committee, consisting of representatives from the Environmental Protection Agency (EPA), the State of New Mexico, and DOE negotiated and established stringent criteria on the form of waste acceptable at the Waste Isolation Pilot Plant'

(60).[14] Although some waste may be certified acceptable at the point of generation, other waste must be treated because it is known to be noncertifiable or because there is uncertainty about its contents (60). Plans call for a five-year test phase at WIPP, followed by a decision as to whether or not the disposal phase should proceed.

WIPP was not designed to serve as a repository for disposal of pre-1970 buried TRU waste, and DOE has no plan yet for the disposal of that waste, should it be removed from any existing sites. Some form of treatment of buried TRU waste in place (in situ) is a distinct possibility.

WlPP[15] was originally scheduled to begin accepting waste in 1988. As of July 1990, although construction of the facility was essentially complete, no TRU waste had been placed in WIPP on any basis, experimental or otherwise. In June 1990, Secretary of Energy James Watkins made a positive ''readiness decision, asserting that DOE was ready to move ahead with a test phase that would involve placement of a small amount of the contact-handled TRU waste eventually planned for disposal. The experimental phase is expected to begin in 1991. If a positive decision is made to utilize WIPP as a disposal facility, such operations could probably not begin until 1995 or later. Many obstacles must be overcome before WIPP can fulfill its mission and the outcome remains uncertain. WIPP is discussed later in this section.

Because TRU waste is stored at a minimum of six Weapons Complex sites, a variety of facilities and equipment exist for its handling and interim storage. Some of these facilities were developed after the 1970 decision to retrievable store TRU waste but before the 1980 decision to proceed with WFP. Several sites began certifying waste for WIPP in the mid 1980s. Existing facilities include the Stored Waste Examination Pilot Plant at INEL; the TRU Storage and Assay Facility at Hanford; the Size Reduction Facility, Treatment Development Facility, and three other facilities at Los Alamos; the TRU Waste Examination, Assay Facility at Oak Ridge; and the Waste Certification Facility at Savannah River. The Rocky Flats Plant also certifies virtually all of its TRU waste at its own facility (56).

Figure 2-5 from the 1989 Five-Year Plan summarizes the six new facilities planned to begin operation during 1992-99 for processing, treating, and certifying TRU waste-both retrievable and newly generated—for shipment to WIPP. According to the 1989 Five-Year Plan, the Processing Experimental Pilot Plant (PREPP) in Idaho will be the first facility to process currently uncertifiable TRU waste;[16] it will shred, incinerate, grout, and produce 55-gallon drum packages. Also at INEL, the Retrieval Con-,tainment Building (RCB) will allow for year-round storage of drums in weathertight containment; the Transuranic Waste Treatment and Storage Facility will provide for examination, handling, shredding, compaction, and repackaging of container contents. The Transuranic Waste Facility at Savannah River will retrieve waste from storage and will vent, purge, shred, and repackage drums; reduce the size of and repackage bulky waste; and solidify liquid waste. The Waste Receiving and Processing Facility at Hanford will inspect packages and perform assaying, repackaging, size reduction, compaction, sorting, shredding, and waste immobilization in grout. If DOE decides it is necessary, incineration will be included between the shredding and grouting operations. The Waste Handling and Packaging Plant at Oak Ridge will process retrievable stored and newly generated TRU waste into a WIPP-acceptable waste form; it will also process remotely handled TRU waste (60).

A June 1987 DOE document estimates that TRU waste management costs for stored and newly generated waste will be $3 billion through the year 2013; this figure is subject to modification. Cost estimates of remedial action for buried TRU-contaminated waste and soil range from between $200 million and $2 billion if waste and soil are left in place, to between $6 billion and $10 billion if they are exhumed and disposed of in a repository (57).

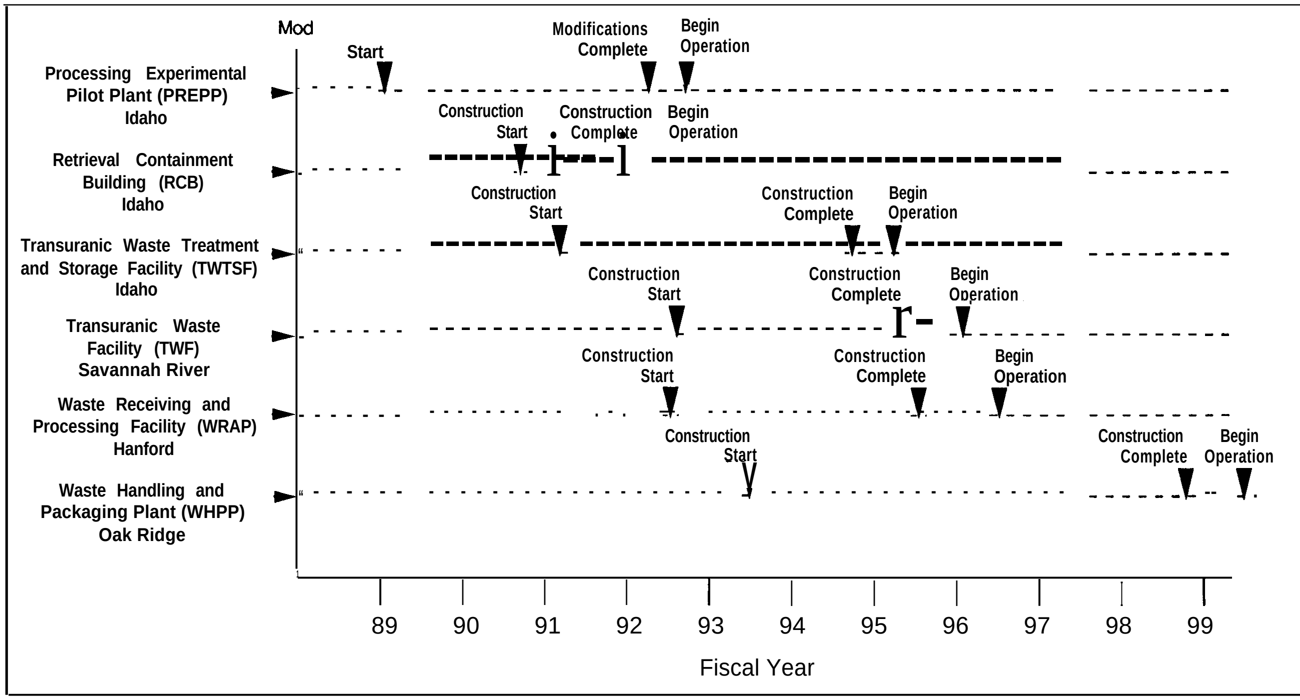
Figure 2-2 shows the points of origin and storage sites for TRU waste. Note that there are more generators than storage locations. Of particular interest is the movement of TRU waste from Rocky Flats to INEL, a path that has been blocked by the Governor of Idaho since September 1, 1989, leading

[14] Establishing the criteria appears to have been solely a DOE responsibility because both EPA and New Mexico's Environmental Evaluation Group have served on the committee in an advisory capacity only.

[15] The Waste Isolation Pilot Plant was authorized by the Department of Energy National Security and Military Applications of Nuclear Energy Act of 1980 (Pub. L. No. 96-164).

[16] Although PREPP is shown with a 1992 start date in the 1990 Five-Year Plan, its future, as of late 1990, is uncertain.

Figure 2-5-Planned Facilities To Process, Treat, and Certify Transuranic Waste for Shipment to the Waste Isolation Pilot Plant



SOURCE: U.S. Department of Energy, "Environmental Restoration and Waste Management: Five-Year Plan," DOE/S-0070, 1989.

to what has been called a storage crisis for Rocky Flats TRU mixed waste.

Current and Potential Problems

Buried Waste and Contaminated Soil

During the roughly 25 years of the nuclear era prior to 1970, waste ,contaminated with TRU elements was not distinguished from LLW and was disposed of in the same manner. Such disposal usually consisted of dumping contaminated clothing, metal, glass, other objects, and liquids into the soil or into solid trenches that were covered with soil. Information on how much, and where, such waste is located at DOE weapons sites is incomplete. The Integrated Data Base (77) indicates that the largest volume of buried TRU waste is located at Hanford, whereas the highest radioactivity of TRU waste is buried at INEL (see table 2-3). In addition, the IDB also gives some inventories and characteristics of soil contaminated. with TRU waste, with INEL having the largest volume (see table 2-2); however, the degree of uncertainty is evident from the manner in which the volume is listed, ranging from 56,000 to 156,000 cubic meters. Furthermore, values of radioactivity for four of the six sites listed in table 2-2 are said to be unknown.

Information about buried TRU waste sites and TRU contaminated soil is far from complete. Information is scarce about the location of these sites, the extent and makeup of contamination, and the extent of migration of radioactive nuclides. A coordinated effort to explore the history of the sites, employing—among other techniques-inter-views with retired workers, could aid in locating and characterizing buried TRU waste.

Throughout the DOE Nuclear Weapons Complex, TRU waste was buried prior to 1970 under conditions that led to the uncontrolled release and migration of radionuclides into the environment. Various DOE Environmental Survey reports indicate that buried TRU waste has caused environmental contamination in at least three facilities: the Savannah River Site, INEL, and Los Alamos National Laboratory. Data on the extent of contamination from buried TRU waste at these and other sites are sketchy, but the following examples provide some insight into possible risks.

1. *Idaho National Engineering Laboratory:* At INEL, TRU waste was received for nonretriev-

Table 2-3—Inventories and Characteristics of DOE Buried Transuranic Waste Through 1988

Site	Values reported by storage site as of Dec. 31, 1988		
	volume (cubic meters)	Mass of TRU nuclides (kilograms)	TRU alpha radioactivity (curies)[b]
Hanford[a]	109,000	346	29,200
Idaho National Engineering Laboratory	57,100	357	73,267
Lawrence Livermore	14,000	53.5	9,230
Oak Ridge National Laboratory	6,200	5.6	270[c]
Sandia	3	1	1
Savannah River Site	4,534	9.1	9,831
Total	190,837	771.2	121,799

[a]Includes soil mixed with buried waste.
[b]As reported by storage sites, it does not include beta and gamma radioactivity or radiation from decay products.
[c]Total of all radioactivity.

SOURCE: U.S. Department of Energy, "Integrated Data Base for 1989," DOE/RW-0006, November 1989.

able burial in shallow pits from 1954 to the 1960s at the Radioactive Waste Management Complex (RWMC), an area that expanded from 13 to 88 acres during this period. An environmental survey performed in 1987 included a review of monitoring records; interviews with EPA, DOE, and State personnel; and sampling and analysis of selected media. According to preliminary DOE survey results (66), plutonium-238 and 239 and americium-241 were detected at above-background levels in the RWMC, with the highest concentrations in surface soil at the perimeter drainage area where water drains from the top of the subsurface disposal area (SDA). Plutonium contamination was detected and americium contamination, was estimated to have moved thousands of feet from the burial site. High concentrations of contaminants near the perimeter of the site were believed due to floods in 1962 and 1969, as well as to localized drainage of water from the surface. Lower concentrations away from the site perimeter were believed to result from wind transport. On completion of these studies, portions of the burial ground were covered with additional topsoil from noncontaminated areas and seeded for ground cover. Other improvements were also made, such as grading to improve drainage and to lower the potential spread of contamination.

According to the INEL survey, studies indicate the presence of plutonium-238 and 239 at the 110-foot interbed beneath the RWMC. The present contractor, EG&G, claims that the concentrations involved do not present a health concern for the near future, because the plutonium is strongly bound to soil particles in the sediment of the interbed layer. This contrasts with the relative ease of plutonium transport through fissured lava. Groundwater is located some 200 feet beneath the RWMC and is contaminated with volatile organic compounds. The survey expressed concern that plutonium could have migrated with these organics but to OTA's knowledge, no evidence of this has been reported.

2. Los *Alamos National Laboratory* (LANL): At LANL, the first solid waste disposal area, a 6-acre landfill known as MDA-B, opened in 1945 and closed in 1950. DOE has stated that radioactive waste in the landfill is likely to include plutonium, polonium, uranium, americium, curium, lanthanum, actinium, and mixed fission products. Waste was reportedly packaged in cardboard boxes or wrapped in paper; an inventory of waste volume and radioactivity is not available. Hazardous waste chemicals placed in MDA-B include organics, perchlorates, ethers, solvents, and corrosive gases.

It is uncertain whether the landfill is one large, continuous pit or a series of six pits. During its operation, waste was probably not covered daily and spontaneous fires also occurred. These past operational practices could have allowed contaminants to migrate beyond the present fenced portion of the landfill, which is located very close to the edge of a mesa top; therefore, the canyon wall on the downslope side of MDA-B may have received contaminated runoff. In addition, waste placed in MDA-B may be a continuing source of contamination to subsurface soil and the vadose zone (67).

Similar contamination may have occurred from the MDA-C inactive landfill, which operated from 1948 to 1974 for disposal of both radioactive and chemical waste. As of January 1973, approximately 50,000 curies of radioactive material was present, including uranium isotopes, plutonium-239, americium-241, tritium, fission products, and induced radioactivity; chemical waste included pyrophoric metals, hydrides, powders, and compressed gases. Waste pits and most of the waste shafts were unlined. Only in 1984 were surface stabilization measures completed at MDA-C, which may help to reduce the potential for downward migration of contaminants.

3. *Savannah River:* Here, the Radioactive Waste Burial Grounds are used for disposal of a variety of waste, including TRU waste. Until 1965, TRU waste was loaded into plastic bags and cardboard boxes that were buried in earthen trenches. Between 1965 and 1974, TRU waste was segregated into two categories: waste with a radioactivity level of 0.1 curie per package or higher was either buried in retrievable concrete containers or encapsulated in concrete; waste with radioactivity lower than 0.1 curie per package was buried unencapsulated in trenches. Since 1974, TRU waste with radioactivity higher than 10 nanocuries per gram has been stored on an interim basis in watertight containers that can be retrieved intact up to 20 years from the time of storage. DOE monitoring wells have detected contaminated groundwater within and at the edges of the burial ground. The gross alpha levels measured are several times those permitted by drinking water standards. According to the DOE 1987 Environmental Survey for the site, monitoring and characterization are quite incomplete (68,93).

In 1987, DOE set forth, in general terms, a plan for buried TRU-contaminated waste and soil as follows: "to characterize the disposal units; assess the potential impacts from the waste on workers, the surrounding population, and the environment; evaluate the need for remedial actions alternatives; and implement and verify the remedial actions as appropriate" (57). However, DOE has just begun this process. Characterization of, and strategies for dealing with, buried TRU waste and contaminated soil are in the very early stages.

A panel of the National Academy of Sciences is monitoring the DOE environmental restoration program dealing with buried TRU waste at INEL. At a November 1989 meeting of the panel, some of the problems encountered were summarized by DOE as follows: "site characterization needs to be much more developed;" ''waste migration needs better definition;" "a decision process [for what to do with the buried waste] with well-developed evaluation criteria needs to be implemented;" and "where the waste would be placed, once retrieved, is open to question."[17] With regard to the last point, it was also stated that DOE may not want to set a precedent by removing buried waste from Idaho.

A number of specific technical studies conducted for DOE were reported at the National Academy of Sciences meeting. One of these highlights a problem associated with buried waste, namely, the development of volatile organic compound plumes beneath the surface that might serve to accelerate the movement of radionuclides beneath the soil to groundwater. Efforts are underway to characterize the carbon tetrachloride plume in the vadose zone under the RWMC area at Idaho and to demonstrate a technology known as vapor vacuum extraction for removal of subsurface organic vapors.[18]

Waste Storage

Implementation of the 1970 decision to store TRU-contaminated waste so it would be retrievable for future disposal in a geologic repository has resulted in waste being stored at several DOE sites, usually in 55-gallon steel drums placed on concrete or asphalt pads. The integrity of the drums is of concern for two reasons: drum storage was meant to bean interim measure, and some drums have already held TRU waste for 20 years, the nominal design lifetime for these packages (55); and the WIPP repository is not expected to accept TRU waste for disposal until 1995 at the earliest, and possibly much later. Furthermore, after WIPP does open, it will take 20 to 30 years to fill the repository and a significant portion of DOE's TRU waste will still have to be stored for long periods of time pending shipment to WIPP.

[17] Statements made by a U.S. Department of Energy representative during summation at National Academy of Sciences Panel to Review the DOE Assessment of Pre-1970 Buried Waste at the Idaho National Engineering Laboratory, Nov. 14, 1989.

[18] R.R. Piscitella, EG&G-Idaho, ''Vapor Vacuum Extraction Demonstration Update, " presentation with view graphs to National Academy of Sciences Panel to Review the DOE Assessment of Pre-1970 Buried Waste at the Idaho National Engineering Laboratory, Nov.13, 1989.

The Pad A Initial Retrieval Project at INEL was defined as part of a Resource Conservation and Recovery Act (RCRA) Facility Investigation Work Plan to determine, among other things, waste container integrity for drums of TRU waste received from Rocky Flats and stored at INEL in 1970-77, as well as associated radiological or hazardous contamination of the soil. In 1989, eight drums were reportedly retrieved from Pad A, of which six had rust holes up to 4 inches long; an EG&G project engineer is quoted as saying that even where the drums have corroded, internal polyethylene bags have contained the waste, mostly contaminated clothes, tools, and rags (12).

Along with the obvious technical concerns about container integrity, there are also regulatory problems. Much of DOE's stored TRU waste is mixed waste; that is, it has both radioactive and hazardous components. The duration of TRU waste storage at a particular DOE site is limited by EPA land disposal restrictions for mixed waste.

State governments are a major factor in regulating stored TRU waste. A situation that received a great deal of attention during 1989-1990 began on September 1, 1989, when the Governor of Idaho refused to permit further shipment of TRU waste from Rocky Flats to INEL (42).[19] The State of Colorado had established a limit to the amount of mixed TRU waste that could be stored at Rocky Flats. At first, DOE was quite concerned that the limit would be exceeded rapidly, forcing shutdown of Rocky Flats plutonium fabrication operations. However, the situation eased somewhat as a result of several factors: Rocky Flats has been shut down since late 1989 for various safety reviews and is thus generating less waste; efforts are moving ahead to assay or reassay stored TRU waste; both waste minimization and efforts to separate the hazardous and radioactive components of TRU mixed waste have reduced storage space requirements.[20] In April 1990, the situation took another dramatic turn when a Federal District judge in Denver ruled that thousands of drums of plutonium-containing material that DOE had considered "residue' (i.e., material from which plutonium would be recovered for future use) was in fact mixed waste subject to the State of Colorado imposed storage limit under RCRA (88). If this ruling were to be implemented, the Colorado storage limit for mixed TRU waste would have been exceeded. However, to date, the State of Colorado has not pursued implementation of this ruling and, instead, has been negotiating an agreement with DOE to resolve this matter.

DOE is pursuing several alternatives, mostly in response to the Rocky Flats situation for storage of mixed TRU waste. These include persuading the Governors of several States with weapons sites to accept some portion of the Rocky Flats waste; storing the waste at Department of Defense facilities; and storing the waste at a privately owned facility .21 In February 1990, DOE announced that it was seeking proposals of plans for a privately owned and licensed facility for interim storage of TRU waste, including transportation from DOE generator sites and subsequent shipment to WIPP for disposal (91);[22] the waste would remain the property of the Federal Government.

Plutonium Handling and Contamination at Rocky Flats

The Rocky Flats Plant is DOE's facility for fabricating, assembling, and quality testing components to be placed in the triggers of thermonuclear weapons. As such, it carries out various plutonium, uranium, and beryllium production activities, as well as recovery by chemical processing of plutonium and americium from retired weapons and fabrication process residues (21). Its plutonium mission makes Rocky Flats a major generator of TRU waste.

Problems reported to have occurred at Rocky Flats since it began operating in 1952 include contamination, injury, and death of workers, attributed to accidents, spills, and fires (l). Retired Rocky Flats workers are suing for compensation, alleging that their cancers were due to radiation exposure. A 1957 fire resulted in release of an unknown amount of plutonium to the air; soil was also contaminated. In January 1990, eight current Rocky Flats workers and four retired workers had reportedly tested

[19]GAO has concluded in a June 1, 1989, letter opinion to Representative Synar that there was no legal authority for the Governor's action. However, DOE has not pursued legal action to reverse it.

[20]U.S. Department of Energy congressional briefing on WIPP Decision Plan and Alternative Storage for Rocky Flats Plant Transuranic Waste, Feb. 22, 1990.

[21]Ibid.

[22]Ibid., viewgraphs.

positive for berylliosis, an incurable disease that results from exposure to beryllium dust and is fatal to about 30 percent of those who contract it (9). Also in January 1990, two labor unions and Rocky Flats area residents filed two class-action lawsuits against Rockwell International Corp. and Dow Chemical Co., the two primary operating contractors at Rocky Flats prior to EG&G, alleging that careless and negligent treatment of hazardous waste had threatened their health and hurt them financially (10). In 1988, the State of Colorado cited Rocky Flats for nine violations of hazardous waste disposal laws.

There has been persistent concern about plutonium releases to the air, as well as plutonium contamination of soil and groundwater. These concerns have received increased attention because 1.4 million people live within 50 miles downwind of the plant.

A 1989 report by Scientech, Inc., indicated the presence of plutonium in ventilation pipes downstream from certain falters that should have prevented it from getting there. The Scientech team concluded that a criticality[23] incident had not taken place but indicated that such an occurrence was not impossible under certain circumstances; the report was critical of Rockwell management practices (41). More recently, EG&G revealed that ventilation piping and ducts contain 28 kilograms of plutonium, more than twice that estimated by the Scientech team and enough to make six or seven nuclear weapons (38).

The DOE ‘‘Tiger Team''[24] report on Rocky Flats was released in August 1989 (54). Figure 2-6 is a summary of the principal observations listed in the executive summary of the report. The seriousness of the Rocky Flats situation is evident from the information presented above as well as the following: a June 1989 raid on the plant by the Federal Bureau of Investigation to investigate various violations, including the alleged running of an incinerator to burn hazardous waste against orders (7); withdrawal of Rockwell International as the principal operating contractor for the plant, with EG&G assuming responsibility; extended curtailment and shutdown of Rocky Flats operations, beginning in November 1989, followed by a series of safety reviews and evaluations (3); and the fact that Rocky Flats was considered by newspaper editors and broadcast directors to be the most important news story in Colorado for 1989 (6).

Figure 2-6-DOE Rocky Flats Tiger Team Report

Observations

- **No situations that pose an imminent threat to public health or the environment were observed.**
- **Implementation of the environmental programs lacks coordination and is hindered by poor communication. The lines of authority and responsibility are fragmented and not clearly defined. A strategy that integrates the existing management and information systems needs to be developed and implemented.**
- **Environmental monitoring programs require improvements to more accurately characterize and monitor plant-related emissions, discharges, and ambient renditions.**
- **Effective implementation of the site remediation program has been adversely impacted by poor communications, coordination, planning, and scheduling.**
- **The quality and reliability of sample collection, laboratory analyses, and other information generated in support of the environmental monitoring and restoration programs are not adequate to achieve program goals.**
- **Management and maintenance of the sewage treatment plant has low priority, resulting in inefficient operation, which could create problems in meeting future permit requirements.**
- **The 1987 Waste Stream Characterization Study, which is used to support waste management activities (e.g., permits and waste classification), does not reflect current waste processes at the plant. The study has never been fully reviewed. Consequently, internal inconsistencies exist. The scope of the study was not broad enough to serve as an effective waste management tool.**
- **A comprehensive strategy needs to be developed and implemented for performing ‘activities required by the National Environmental Policy Act.**

SOURCE: Summarized from U.S. Department of Energy, “Assessment of Environmental Conditions at the Rocky Flats Plant,” DOWEH-107, August 1989.

Waste Assay, Treatment, and Certification

DOE is faced with the task of assaying its stored waste to determine what portion may properly be classified as TRU waste. Previously, DOE had assumed that if there was any uncertainty about the nature of stored waste, it would be handled as TRU waste. More recently, because of concerns about finding suitable interim storage for TRU waste, coupled with advances in assay technology, DOE has been assaying previously stored TRU waste to

[23]A criticality incident involves the unintentional buildup of fissile material such as plutonium-239 in an amount and geometry that would form a critical mass, in a piece of equipment not designed to contain neutron chain reactions. Consequences could include a major uncontrolled release of radioactivity. “A criticality accident at the Rocky Flats Plant could produce a potentially lethal dose of neutron and gamma radiation to workers at close range, could generate heat and fission products, and, in extreme but low probability circumstances, could result in the release of radioactivity to the environment” (41).

[24]During 1989 and 1990, DOE has conducted investigations of health, safety and environmental problems at each site utilizing an ad-hoc group specially selected by DOE headquarters. These groups are known as Tiger Teams.

determine if some portion of that waste can be reclassified, treated if necessary, and disposed of less expensively as LLW. An additional factor driving reclassification was the redefinition of the lower radioactivity limit for TRU waste from 10 to 100 nanocuries per gram in 1982. Based on sampling procedures and work to date, DOE estimates that 38 percent of its current inventory of retrievable stored TRU waste will be reclassifiable as LLW (79).

In November 1989 DOE reached agreement with the State of Colorado to assess the substantial quantities of plutonium 'residues' from incinerator operations at Rocky Flats to determine whether they have been properly classified or whether some portion should be considered TRU waste (37). In April 1990, a Federal district judge ruled that the materials in question did in fact constitute waste; DOE acknowledged that plutonium had been recovered from less than 10 percent of these residues during the past 5 years (88).

The certification of TRU waste involves two major steps. First, the waste must correspond to the definition of TRU waste, which currently excludes TRU-contaminated materials with alpha radioactivity lower than 100 nanocuries per gram. Second, according to current DOE plans, the waste package must meet Waste Acceptance Criteria for disposal in WIPP. Criteria for contact-handled TRU waste and remote-handled TRU waste were established in 1980 and are listed in the 1990 final supplement to the Environmental Impact Statement (EIS) for WIPP (69). Some of the existing stored TRU waste drums are or will be certifiable for shipment to WIPP as is. Others will have to be treated at one of the facilities planned to be developed by DOE.

The Waste Acceptance Criteria now in effect would allow a variety of waste contents and forms within the package to be placed in the WIPP repository. In general, TRU contaminants would not be immobilized in either the contact-or the remote-handled packages, and thus would be respirable and soluble if released. This is in marked contrast to the more uniform vitrified packages of high-level waste with immobilized radionuclides planned for emplacement in the high-level waste repository. Some of the remote-handled TRU waste packages for WIPP can have external dose rates as high as 1,000 rem per hour, exceeding that of some HLW vitrified glass logs. Even though only a small portion of the TRU waste is classified as remote-handled, it may be prudent to investigate the integrity of this waste package in more depth.

In preparation for WIPP operations, DOE is examining engineering alternatives for the WIPP waste package, driven in part by concern about gas generation after it is in the repository. It may be both necessary and desirable to modify the WIPP waste package to reduce or eliminate gas generation. Two possible classes of alternatives are: to shred, compact, and perhaps grout the waste; and to incinerate, calcine, or vitrify it.[25] The latter alternative would represent a major departure from current plans. Vitrification could eliminate gas generation in the repository and result in a more stable waste form. Disadvantages of vitrification are that it would require a major overhaul of current plans and treatment facilities at considerable expense and could possibly increase occupational exposure. A thorough analysis of these alternatives would be required before an informed choice could be made.

Transportation of Waste

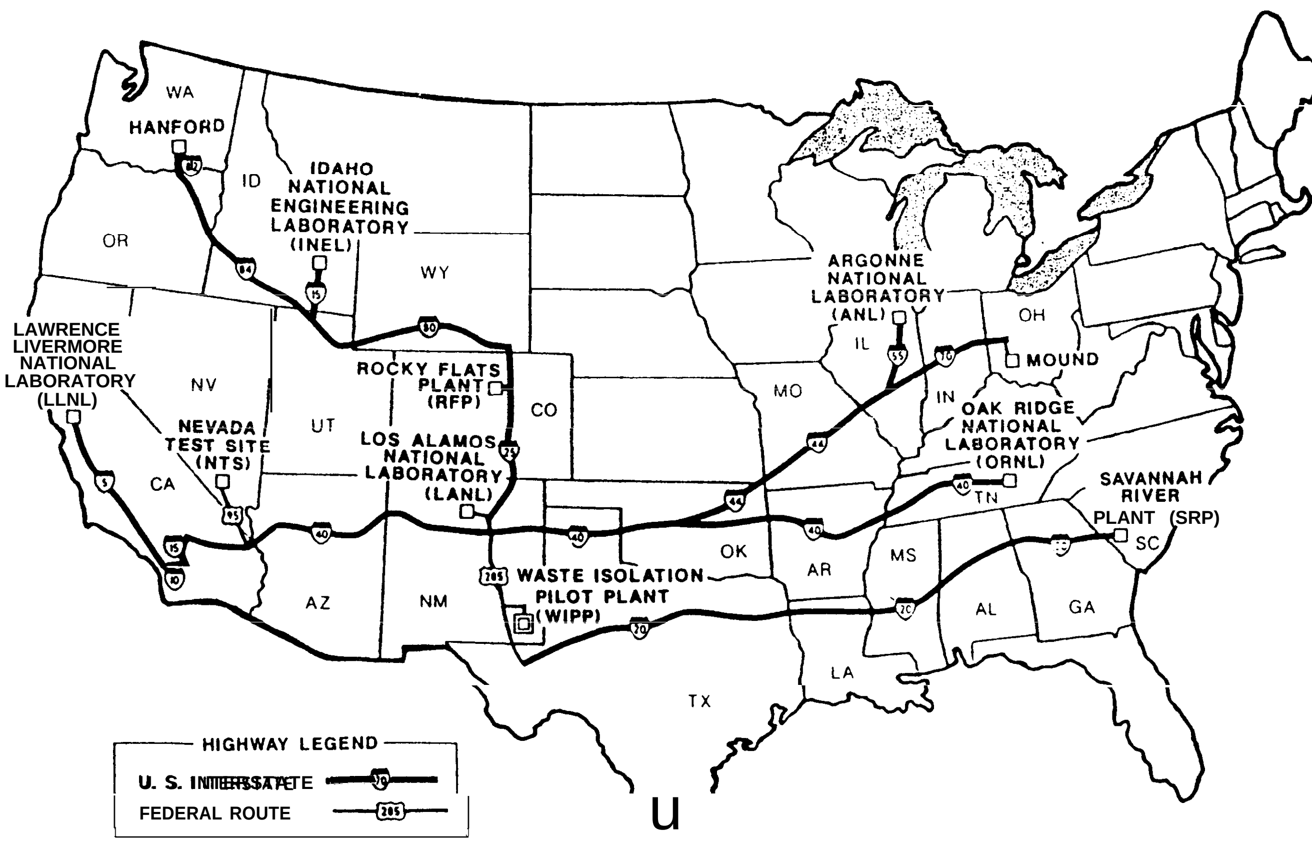
Figure 2-7 shows the proposed transportation routes to WIPP. TRU waste is currently located at the DOE sites identified in the figure and must be transported over relatively long distances. Transportation of waste packages to WIPP represents the area of greatest public concern, as measured by the number of comments received about this topic in connection with the WIPP Supplemental Environmental Impact Statement (SEIS) (70).

The transportation option chosen by DOE is a fleet of trucks carrying the waste in specially designed "TRUPACT II" containers (see figure 2-8). The container design has been certified by the Nuclear Regulatory Commission (NRC) as suitable for shipping contact-handled TRU waste drums to WIPP.[26] A number of concerns have been expressed about the shipping plans including preparation for emergency response to traffic accidents, qualifications of the trucking contractors, specific routes used by the trucks, validity of accident analyses and structural integrity of the container (70). In addition to addressing these concerns in the SEIS, DOE has attempted to enhance safe transport by: developing a program to train State, local, and Indian tribal police and emergency personnel in proper proce-

[25] Neill, R., Environment Evaluation Group, personal communication, Mar. 26, 1990.

[26] For about a decade, DOE pursued a rectangular container design that was abandoned after failure to meet DOE's own standards.

Figure 2-7—Proposed Shipping Routes to the Waste Isolation Pilot Plant



SOURCE: U.S. Department of Energy, "Environmental Restoration and Waste Management: Five Year Plan," DOE/S-0070, 1989, p.144.

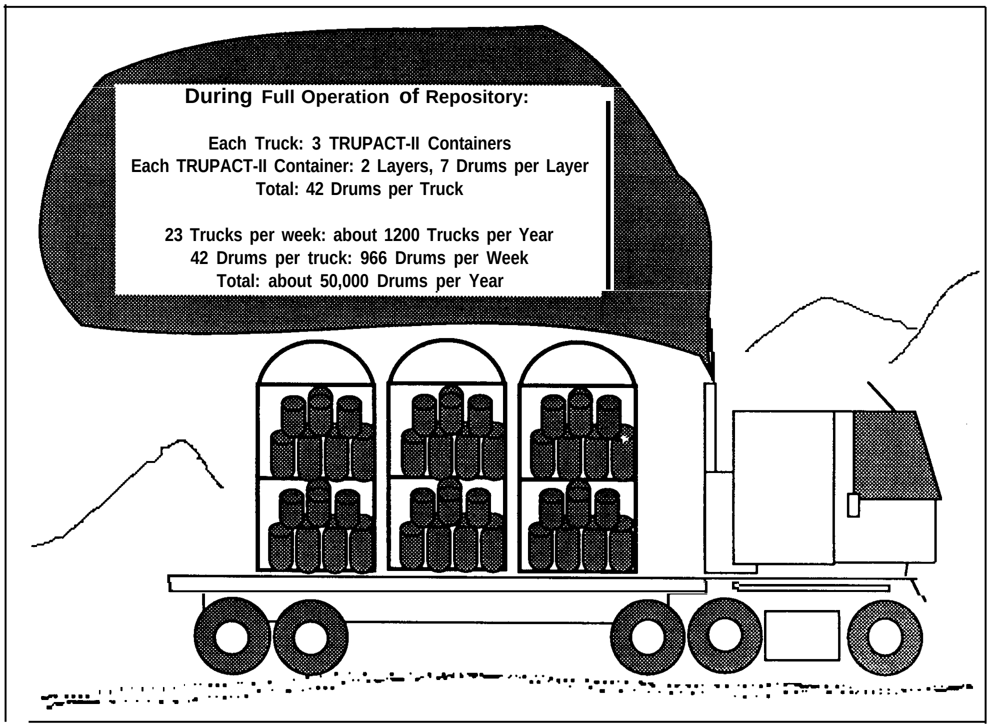
dures following an accident; developing a satellite tracking and communication system for the trucks; and providing an extensive public information program for persons and officials in the 23 affected States and Indian tribal governments along the WIPP route (71).

Despite DOE statements that the containers and trucks are safe, opposition to the transportation of TRU waste to WIPP is likely to continue. Among the concerns expressed at April 1990 hearings of the New Mexico State Environmental Improvement Board was a distrust of statements that there is little, if any, risk to public health and safety from the radioactive waste, either during transport or in WIPP itself (2,1 1). Transportation will bring the waste close to many people, and expressions of opposition have ranged from signs in Santa Fe reading "Another Business Against WIPP" to threats of civil disobedience.

In a March 1990 analysis of the risk of transporting contact-handled TRU waste to WIPP, the Environmental Evaluation Group (EEG) concluded that "the currently identified routes do not pose a statistically significant health risk to New Mexico residents, and it is not expected that any other routes which may be so designated for this purpose will pose a significant health risk" (25). EEG recommends that truck crew members be closely monitored to ensure exposures less than 2 millirems per hour, that selection of truck stopping places be carefully studied to minimize unnecessary exposure, and that bypasses around communities be used when possible (25).

To minimize the possibility of confrontation and avoid taking waste through urban areas, the State of New Mexico has sought funds to build a bypass around Santa Fe and other communities. At an April 1990 Senate Energy Committee hearing on WIPP, Secretary of Energy James D. Watkins and Senator Peter Domenici of New Mexico disagreed on whether the DOE was reneging on a commitment to

Figure 2-8-Bringing Trucks of TRU Waste Drums to the WIPP



SOURCE: Office of Technology Assessment, 1991.

provide $250 million for New Mexico road construction.[27] New Mexico officials believe they had such a commitment of funds from DOE, whereas Secretary Watkins asserts that the commitment was to help obtain funds and not to provide them. States other than New Mexico through which the waste will pass are interested in the outcome of this controversy because they have road-building needs and desires of their own.

Finally, the question arises, what should be done if waste packages arrived at WIPP that were either damaged or uncertifiable for placement in the repository? WIPP appears to have very limited capability for handling damaged packages, as well as limited storage capacity. Also, there is no approved, above-ground storage facility at WIPP for mixed TRU waste.

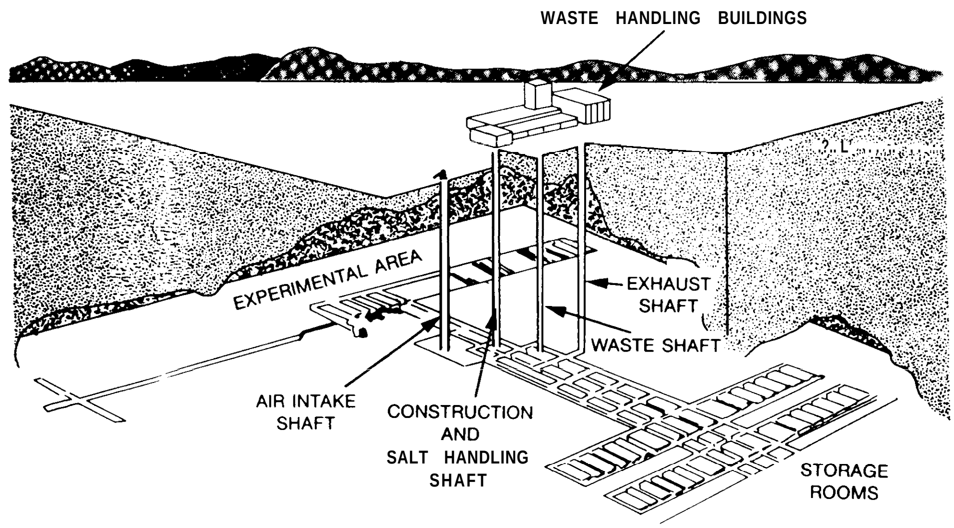
The Waste Isolation Pilot Plant

The Waste Isolation Pilot Plant near Carlsbad, NM, is a key element in DOE's management strategy to dispose of retrievable stored and yet-to-be-generated TRU waste in a deep geologic repository, specifically, rooms mined in bedded salt 2,150 feet below the-surface (see figure ***2-9). The*** DOE 1989 Five-Year Plan calls for a 5-year demonstration or test phase to prove the WIPP concept will be undertaken. At the end of this demonstration phase, a decision will be made as to WIPP's acceptability as a permanent, operational, disposal facility for TRU waste. According to the Five-Year Plan, the 5-year test phase has two main objectives: to demonstrate that there is reasonable assurance of compliance of the WIPP disposal system with long-term EPA disposal standards, and to demonstrate the ability of DOE's TRU waste management system to safely and effectively certify, package, transport, and emplace waste at WIPP. After the test phase, the plan indicates that DOE will evaluate whether WIPP should proceed to the disposal stage (62).

Construction of the WIPP facility is essentially complete and WIPP was originally scheduled to open in 1988. It now appears that the first test phase could begin sometime in 1991 but opening date predictions are very difficult to make. Although

[27] From Senate Energy Committee hearing on WIPP, Apr. 3, 1990. See also *Weapons Complex Monitor*, "EPA Proposes to OK DOE WIPP Test Phase No-Migration Petition," Apr. 18, 1990, pp. 2-3.

Figure 2-9-The Waste Isolation Pilot Plant: Its Capacity, Estimated Operational Cost, and Estimated Lifetime



Total waste capacity:	6 million cubic feet
Current accumulated waste volume:	2.12 million cubic feet
Construction cost to date:	$700 million
Estimated cost for 25-year operation:	$2.5 billion
Estimated total time to fill the WIPP repository:	20-30 years

SOURCE: Office of Technology Assessment, U.S. Department of Energy.

considerable progress has been made in overcoming a sizable number of technical, regulatory, safety, and procedural obstacles, further obstacles and questions concerning the opening of WIPP remain to be addressed.

WIPP's importance extends beyond its role as a repository for TRU defense waste. To DOE Secretary Watkins, it represents an opportunity to makeup for past mistakes and prove the competence of U.S. science and technology.[28] For others, it represents moving forward with the long-term disposal of radioactive (TRU) waste in an existing facility, whereas a high-level waste repository seems a more distant possibility. Some undoubtedly see the successful outcome of WIPP, not withstanding its defense mission, as a giant step forward for civilian nuclear power by demonstrating that radioactive waste can be disposed of somewhere and need not accumulate at reactor sites. Thus, a variety of pressures may make it difficult for DOE to determine fairly and objectively at the end of a test phase whether or not TRU waste can be deposited safely in WIPP. DOE'S thrust is summarized in the following statement in the 1989 Five-Year Plan: "A positive determination by DOE and continuing shipments to WIPP . . . would mean fulfillment of a major DOE objective" (62).

A variety of mechanisms have been put in place that provide useful technical advice and a measure of oversight for WIPP. They include a DOE Blue Ribbon Panel, a National Academy of Sciences panel, a subcommittee of the DOE Advisory Committee on Nuclear Facility Safeguards, and the EEG. Of these, EEG is the only organization with a substantial full-time technical staff; it has been a continuing source of valuable technical advice and oversight for WIPP since its inception. Although EEG's funds come from DOE, it is associated with

[28]Secretary of Energy James D. Watkins, testimony at hearing on WIPP before Senate Energy Committee, Apr. 3, 1990.

the State of New Mexico.[29] Other oversight groups have also provided important technical advice but because they are either volunteer panels with minimal staff that only meet occasionally or because their scope and duration of oversight is limited, their ability to make in-depth evaluations is limited.

Problems With WIPP--Some of the technical problems confronting WIPP were summarized at the 1989 Waste Management Conference. At that time, according to EEG, DOE had not published a single report to document WIPP's progress toward compliance with EPA Standards for the Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes (40 CFR Part 191). Among the technical problems were brine inflow and associated scenarios, the need to designate backfill materials, and the need to carry out a WIPP performance assessment, including experiments as opposed to pure modeling. Operational readiness issues were also unresolved. In addition, waste handling dose criteria were said to be less stringent than for commercial operations because they were essentially DOE self-regulated rather than NRC-regulated.[30]

EEG has monitored a variety of WIPP activities. For example, in 1989, in observations pertaining to the WIPP Phase II Preoperational Appraisal, EEG found significant programmatic deficiencies in the WIPP operational health physics program.[31] Among the issues that needed to be addressed were technical staffing, control of potential contamination events, training of health physics technicians, improved radiological calibration and maintenance, use of controlled areas for nonradiological functions, internal audits, accreditation of the external dosimetry program, establishment of an internal dosimetry program, establishment of a health physics respiratory protection program, and resolution of effluent monitoring and air monitoring issues. Many of these issues were reiterated a year later.[32] While DOE continues to make progress addressing these issues, it appears that EEG oversight provides a valuable mechanism for checking on such progress.

Brine and Gas Generation-The choice of WIPP as a deep geologic repository for TRU waste was predicated upon making use of a salt bed as the medium for isolating the waste from the environment. The salt would plastically deform and close in on the waste, keeping it isolated from the environment for a sufficiently long period to conform with EPA disposal requirements. Theoretically, one of the virtues of salt was its undisturbed nature; that is, it was initially thought to be dry. An earlier choice of a salt mine in Lyons, KS, as a repository for high-level waste was abandoned after discovery that the area had been extensively mined and that a significant number of boreholes penetrated the supposedly isolated repository (33). At WIPP, although there was no prior intrusion, some water and brine were evident in the repository. The water or brine was not in great evidence during an OTA site visit at the repository in March 1990 because of evaporation, due in part to the ventilation system; however, the brine could be a factor in certain scenarios following closure of the facility.

More recently, the concern about brine has been replaced by a concern about gas generation in TRU waste packages. Given current WIPP waste acceptance criteria, gas generated in the vented drums by a combination of metal corrosion and microbial activity will probably build up in the repository. Gas pressure could reach the point at which it will push outward on the surrounding salt bed;[33] developments beyond that are matters for both analysis and speculation. The analysis is being done by DOE's Sandia National Laboratory (SNL), the principal scientific contractor for the WIPP operation. Speculation at a March 1990 meeting of WIPP advisory and oversight groups convened by the National Academy of Sciences ranged from an optimistic "hoop stresses will hold things together" to a

[29] The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Wrote Isolation Pilot Plant (WIPP) Project to ensure protection of the public health and safety and the environment. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Pub. L. No. 100-456, the National Defense Authorization Act, FY 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and provided for continued funding from DOE through a contract (DE-AC04-89AL58309).

[30] R.H. Neill, Environmental Evaluation Group, paper presented at Waste Management Conference, Tucson, AZ, February 1989.

[31] R.H. Neill, Environmental Evaluation Group, letter to Jack B. Tillman, U.S. Department of Energy, WIPP Project Office, Carlbad, NM, Apr. 7,1989.

[32] R.H. Neill, Environmental Evaluation Group, personal communication to R.P. Morgan, May 1990.

[33] According to a 1989 Sandia report, gas pressure in the mine could increase to a "lithostatic" pressure of 2,150 pounds per square inch in 65 to 70 years (30).

pessimistic "radioactive materials will be released into the environment. '

A June 1990 report of Sandia National Laboratory concluded that "*SNL has reasonable confidence that compliance is achievable* with the (EPA disposal) Standard as first promulgated."[34] However, the report goes on to state that it is "not a formal evaluation of compliance; available data and models are insufficient for a full-scale assessment. ' According to the report: ''The major question remaining is not whether the WIPP can comply with the Standard but rather how it should comply.' Among the options being examined for how to comply are identification of alternatives for the waste form and repository design to improve WIPP's ability to reduce potential releases.

OTA has not analyzed the Sandia Report in detail. The Environmental Evaluation Group finds the report's primary deficiency to be that ''it does not present analyses of breach scenarios involving gas pressurization in the repository. Since the experiments with the waste focus on measuring the rate of gas generation, it is necessary to present analysis of breaches involving this phenomenon, including a determination of the threshold of unacceptable gas generation rate and an assessment of the likelihood of meeting compliance with the standards with or without planned modifications. ' '[35] As a consequence of this and other aspects of the report, EEG finds that the report does not provide "sufficient basis for high confidence that WIPP can demonstrate compliance with the . . . . Standards. "

Another aspect of the Sandia Report is troubling. In the foreword, it is argued that although some readers may disagree, Sandia's positive finding of "reasonable confidence that compliance is achievable without demonstrating compliance" is "logical and must be made at this time. ' The reason given is that predictions of feasibility are essential for R&D projects and must invariably anticipate achieving project objectives. ''National Air and Space Administration was able to predict the achievability of a manned moon landing years before they could demonstrate it. Had realistic predictions of ultimate success not been available in advance, the task might never have been undertaken. ' What is troubling about the NASA analogy is that it equates a relatively high-risk task in space exploration with a task that seeks to ensure the safe disposal of radioactive and hazardous wastes in a manner that minimizes risk to the public and the environment—two very different activities with very different levels of public support and understanding. Furthermore, this philosophy clearly indicates Sandia's role in support of the objectives of the DOE mission; thus, Sandia's conclusion of compliance with the standard, no matter how soundly based, is likely to be questioned. A related question is whether or not there is sufficient independent oversight and analysis capability outside of DOE and its contractor network to scrutinize such analyses and perform them independently, primarily from the viewpoint of public health and safety.

Two approaches might be hypothesized to deal with the problem of gas generation that illustrate the range of possible choices. One is to stay with the current waste form, learn as much as possible about gas generation, assuming that compliance with disposal standards can be demonstrated. The other is to alter the waste form now to reduce or even eliminate the generation of gas; processes for this range from shredding, compaction, and grouting on one hand, to incineration, calcining, or vitrification on the other.[36] As mentioned previously, the latter alternatives could be very disruptive of current DOE plans and could add considerably to the cost and the occupational risk.

Studies of alternative engineering waste forms are part of DOE's decision plan for WIPP. DOE appears to be pursuing somewhat of a middle course in that although we know of no firm plans as of this writing to test alternative waste forms in or for WIPP, such forms represent a fall-back position in case the untreated waste form does not comply with the Standard.

An Engineered Alternatives Task Force (EATF) has been created by International Technology Corp. for Westinghouse, the management and operating contractor for WIPP. The EATF has made preliminary recommendations of 15 possible waste-form treatments for inclusion in WIPP's test program. Six basic forms on the list include glassified vitrified

[34] S.G. Bertram-Howery, and P.N. Swift, "Status Report: Potential for Long-Term Isolation by the Wrote Isolation Plant Disposal System," Sandia Report SAND90-0616, Albuquerque, NM, June 1990.

[35] R.H. Neill, EEG, letter to L.P. Duffy, DOE Aug. 24, 1990.

[36] Eliminating steel drums would avoid anoxic corrosion.

waste, cemented waste, compacted waste, shredded waste with bentonite filler, metal waste melted into ingots, and pH-buffered waste packages. Final recommendations are due in 1991.[37]

The gas generation issue is central to current thinking about the WIPP experimental phase. DOE wishes to move ahead with a series of bin experiments in which gas generation rates will be measured in the repository with real TRU waste. Objections to these experiments include the following: previous measurements indicate that gas generation rates will be unacceptably high; the experiments can be done outside the repository; and WIPP was not designed for handling liquid samples with radioactive Transuranics. Counterarguments for moving ahead include: if the experiments are performed outside of WIPP, it will be argued that they were not done under real-world conditions; and WIPP exists, so it is cheaper and better to do the bin experiments there than elsewhere.

Alcove experiments to test gas generation and brine inflow in somewhat larger spaces are also planned. The bin and alcove experiments will employ about 0.5 percent of all of the waste eventually destined for WIPP, roughly 4,500 waste drums or 100 TRUPACT trailers full of waste. As of June 1990, a proper seal for the alcove experiment had not been achieved.[38] Finally, in April 1990, DOE indicated that, at EPA's suggestion, it would evaluate the possibility of filling two rooms with waste during the test phase, raising the possible emplacement from 0.5 to 2 percent of design capacity and from 100 to 400 TRUPACT trailers.[39]

Disposal Standards; "No Migration"; Land Withdrawal—Two other aspects of WIPP that deserve examination are its performance assessment and its ability to meet EPA disposal standards for TRU waste. At present, assessment of the performance of WIPP is not expected to be completed before the end of 1994. This assessment is likely to be important in determining whether or not WIPP will meet the EPA disposal standards and whether the waste form will have to be changed in order to do so. DOE hopes to proceed with the experiments without having to demonstrate compliance with EPA disposal standards, arguing that the standards should apply only to the operational phase; EPA concurs with this. The relevant EPA standards have been remanded by the courts, and new standards are not expected to be finalized before 1992. At a March 1990 meeting of four WIPP oversight committees, concern was expressed about the ability of WIPP to meet the standards under a human intrusion scenario; although less concern existed about a undisturbed scenario, there was concern nevertheless.[40]

An important step toward proceeding with the WIPP experimental phase occurred when EPA proposed to rule positively on DOE's request for a no-migration variance that would allow emplacement of mixed TRU waste in WIPP for "testing and experimentation to determine whether the site is appropriate for the long-term disposal of mixed waste' (90). The proposed EPA ruling, which was followed by a 60-day public comment period,[41] prohibits DOE from moving ahead with the operational phase and requires it to remove the waste if a ''no-migration' condition of hazardous waste cannot be demonstrated for the long term (90). The proposed ruling indicates that EPA basically supports DOE efforts at WIPP.[42] According to EPA, "Given the geologic stability of the area; the depth, thickness, and the very low permeability of the salt formations in which the repository has been mined; and the properties of rock salt as the encapsulating medium . . . the WIPP is a promising site for a

[37] S.G. Bertram-Howery, and P.N. Swift, ''Status Report: Potential for Long-Term Isolation by the Waste Isolation Plant Disposal System,'' Sandia Report SAND90-0616, Albuquerque, NM, June, 1990.

[38] Subsequently, in October 1990, DOE informed EEG that these tests are not scheduled to start until 1992. They will not be carried out unless an adequate seal can redemonstrated. (See R.H. Neill, EEG, testimony before New Mexico legislative Committee on Radioactive and Hazardous Materials, Carlsbad, NM, Oct. 4, 1990.)

[39] Senate Energy Committee, hearing on WIPP, Apr. 3, 1990.

[40] National Academy of Sciences meeting on public Confidence in WIPP, Mar. 5, 1990.

[41] Among the comments was a joint submission by The Attorney General of Texas, the Hazardous Waste Treatment Council, and four environmental organizations opposing the proposed variance. (See "Joint Comments on the Proposed Conditional 'No-Migration' Variance From Land Disposal Restrictions to the Department of Energy's Waste Isolation Pilot Plant,'' submitted by the Natural Resources Defense Council, The Hazardous Waste Treatment Council, The Attorney General of Texas, Southwest Research and Information Center, Concerned Citizens for Nuclear Safety, and the Environmental Defense Fund, June 5, 1990.)

[42] Some concern has been expressed that EPA was too accommodating to DOE pressure and too hasty in its favorable response to the no-migration petition. In addition, Representative Mike Synar of Oklahoma has criticized EPA for proposing to grant the variance without having disposal standards in place. (See ''Synar Says EPA Pressured To Waive Rules, " Associated Press News Release, May 9, 1990.)

permanent mixed-waste repository" (90). In November 1990, EPA approved DOE's WIPP no-migration petition for the test phase, but imposed several conditions (see app. A).

One hurdle that still remained as 1991 began was withdrawal of the land on which WIPP is located from the public domain. DOE had been pursuing two options in this regard: the preferred option was for Congress to pass a law authorizing such land withdrawal; the other was for the land withdrawal to be handled administratively by the Department of the Interior. However, as Secretary of the Interior Manuel Lujan pointed out, such administrative withdrawal would be for only 20 years; at the end of that time the land would have to be restored to its original condition.[43] Such restoration would be a nearly impossible requirement for a fully operational long-term geologic repository to meet, but it would be sufficient for the test phase for which the waste must be retrievable.

A land withdrawal bill that presumably reflected DOE's position was introduced in Congress during 1990. This legislation placed certain conditions on DOE, some of which had been met (e.g., completion of the Supplemental Environmental Impact Statement) or were in the process of being met (e.g., granting of the no-migration variance).[44] Benefits to the State of New Mexico include the use of local workers and the potential development of local businesses, as well as DOE payments to local governments in lieu of taxes that would have accrued if the land were privately owned (90).

Conditions in the land withdrawal bill seemed to provide DOE with some leeway to move beyond the experimental phase. There was no limit on the volume of waste that could be placed in WIPP; restraints to doing so appear to be mainly verbal assurances from the Secretary of Energy (90). Land disposal legislation could serve as a vehicle for imposing additional conditions on DOE. However, no such legislation was passed during 1990. In January 1991, the Department of the Interior transferred control of 16 acres including WIPP to DOE by the process of administrative withdrawal.[45]

At present, DOE is pushing vigorously to get the first waste for the experimental phase into WIPP. The symbolic value of emplacement of the first waste package could be of equal or greater value than specific technical information likely to emerge from this phase. DOE's technical oversight groups generally support proceeding with the bin and alcove experiments, although substantial sentiment exists in EEG for moving ahead with plans to alter the waste form to reduce or eliminate gas generation and make the waste package more analogous to that for high-level waste, given the parallel disposal approaches for these two categories implied by EPA standards.[46] If the experimental phase is initiated, the performance assessment, including analysis of whether an operational WIPP repository can meet EPA long-term disposal standards not yet promulgated, will be very important during the next 3 or 4 years. The following issues could arise if waste is placed in WIPP before disposal standards are in place.

Analysis of Storage Issues at WIPP—In December 1989, the General Accounting Office (GAO) reviewed DOE's proposed experiments and storage operations at WIPP, in response to a request from Representative Mike Synar prompted by the discovery of brine in what was expected to be a dry repository. GAO summarizes its results as follows (45):

> WIPP is a key part of DOE's plan to clean up its aging defense facilities. By moving TRU wastes from these facilities to WIPP, DOE would be able to address what has become a contentious issue in federal-state relation--continued "temporary" storage of the wastes. However, by storing waste in WIPP years before determining compliance with disposal standards that are as yet uncertain, DOE might have to either abandon WIPP, if it does not comply with the new standards, or remove and/or rehandle wastes in order to comply with the standards. In making a decision on DOE's request to withdraw the land and permit storage to begin, the Congress' choices range from authorizing waste storage in WIPP either with or without restrictions to deferring action until DOE has determined that WIPP complies with EPA's revised standards. The Congress needs to weigh several factors:

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[43] Secretary of the Interior Manuel Lujan, testimony at hearing on WIPP before Senate Energy Committee, Apr. 3, 1990.

[44] The no-migration variance for WIPP was published by EPA in the *Federal Register* on Nov. 14, 1990. The determination to allow DOE to dispose of RCRA-regulated hazardous constituents at WIPP will be limited to testing and experimentation purposes for a period of 10 years.

[45] K. Schneider, "Plan on Starting Nuclear Waste Clears Big Hurdle," *The New York Times*, Jan. 23, 1991.

[46] EEG recommended pursuing only the bin and alcove experiments, nOt the "two-room' or operations demonstration, until DOE proves it can meet the disposal standards.

—If WIPP does not comply with EPA's standards, DOE would either have to remove the wastes from the site, retrieve them for additional processing, or rehandle them to modify the facility and achieve compliance. DOE, however, has not addressed these contingencies in its draft test plan.

—DOE could defer a demonstration of waste storage operations. Deferring the demonstration, however, would delay DOE's removal of TRU waste from other facilities, and states hosting these facilities vigorously oppose additional storage at the facilities.

—The National Academy of Sciences agrees that DOE's planned-gas generation experiments are warranted and should begin but recommends deferring the demonstration of storage operations.

GAO recommended that DOE provide Congress with three categories of information: technical justification for waste storage in WIPP, including the amount to be stored, ''in advance of determining if the facility can be used as a repository'; contingency plans for disposing of waste, experimental or operational, stored in WIPP if the facility does not comply with EPA disposal standards;[47] and options for continuing to store waste at other Weapons Complex sites while DOE assesses WIPP's compliance with standards. GAO also suggested that Congress consider: including a provision in any eventual legislation limiting the amount of waste that could be stored at WIPP until compliance with the standards is achieved; and making permanent land withdrawal for WIPP conditional upon a positive determination of compliance with standards.

The Future of Plutonium Operations at Rocky Flats

According to reports early in 1990, DOE was committed to repairing Building 371 at Rocky Flats, which was opened in 1981 to replace two older facilities (Buildings 771 and 776) and then shut down in 1984 (40). Building 371 has been plagued with problems from the outset; evidently, up to $600 million will be required to make the necessary repairs and additions.

Rocky Flats is the only "source of the plutonium parts that trigger thermonuclear reactions" (40). Arguments for the repair of Building 371 are that existing facilities are getting old, that Rocky Flats is the only place currently reprocessing old warheads (a necessity even with arms control agreements), that plans for a Special Isotope Separation (SIS) plant for plutonium isotopes at Idaho have been abandoned by DOE at least for now, and that opposition exists to the idea of expanding plutonium operations at Los Alamos from research to production. On the other hand, Colorado Senator Tim Wirth has expressed the case against renovating Building 371 as follows: ''The idea of extending the life of a plutonium processing plant in the middle of a major metropolitan area makes absolutely no sense. We are not exactly living at the height of the cold war. What is the rush to build a new facility at Rocky Flats?" (40)

Of immediate concern is whether it will be safe to restart the Rocky Flats Plant after a shutdown for repairs, safety inspections and evaluation, and management changes that began in November 1989. One of the concerns is whether the plant will be allowed to reopen with some or all of the 28 kilograms of plutonium dust in the vents and ducts (38). DOE has stated that the plant will not reopen until it can do so safely; in making this assessment, DOE is receiving input from the Defense Facilities Nuclear Safety Board. However, Congresswoman Patricia Schroeder of Colorado has expressed concern that pressure was being exerted by the defense establishment to restart the plant promptly.[48] This debate illustrates the tension between perceived defense production needs on one hand and environmental or safety concerns on the other.

In a report on modernizing the DOE Weapons Complex submitted to Congress in January 1989, DOE suggested eventually shutting down Rocky Flats and moving its operations to another weapons site. This subject was subsequently reviewed in a September 1989 OTA report (46). More recently, in January 1991, DOE issued a report that supersedes its earlier study and proposes reconfiguring the Weapons Complex into one that "would be smaller, less diverse, and less expensive to operate than the Complex of today.' '[49] In the Reconfiguration Study,

[47] In Nevada the NRC requires DOE to show compliance with long-term disposal standards for high-level wast*before* receiving a license to @@ construction of the Yucca Mountain repository. This requirement exists even though it is very likely that disposal standards will be in place long before a HLW repository opens.

[48] Congresswoman Patricia Schroeder, testimony at hearing of Defense Nuclear Facilities Safety Board, House Committee on Armed Services, Mar. *22, 1990.*

[49] U.S. Department of Energy, Nuclear Weapons Complex Reconfiguration Study, Report DOE/DP-0083, January 1991, Foreword.

relocation of the Rocky Flats Plant is a preferred option of the Secretary of Energy although the time frame for the relocation is not specified and restart prior to relocation is anticipated. Although no reactor production of plutonium is required for any of the weapons stockpile scenarios considered in the study, DOE deems "a modern plutonium recycle and recovery capacity to be essential to extract plutonium from retired weapons and to minimize wastes .50 As DOE continues to study the question of modernizing the Weapons Complex and building new facilities or moving certain functions, it will need to consider carefully the implications for safe waste disposal in the future.

TECHNOLOGIES FOR IMPROVED MANAGEMENT OF Transuranic WASTE

Introduction

This section discusses three treatment technologies that could prove useful for managing retrievable stored TRU waste-incineration, immobilization in grout or concrete, and compaction—as well as one technology for managing buried TRU waste, namely, in situ vitrification. The purpose of improved treatment technologies is to reduce some or all of the following TRU waste characteristics: volubility, respirability, mobility, volume of gas produced, volume of waste, and uncertainty in predicting its behavior in a repository. The three technologies discussed are receiving considerable attention because of their potential or proven utility. One of these, incineration, also tends to be visible because it often meets with public opposition. In situ vitrification probably receives more attention within the Department of Energy (DOE) than any other technology as a relatively new, innovative approach for in-place immobilization of buried waste. DOE's plans for overcoming problems in the management of TRU waste are also outlined in this section. Finally, actinide conversion (transmutation) and waste minimization, as they pertain to TRU waste, are discussed.

Three Technologies for Treating Retrievably Stored Transuranic Waste

Incineration

Incineration (i.e., the burning of hazardous or radioactive materials) is potentially very useful for reducing waste volume and destroying the hazardous component of mixed waste. Because the hazardous component is often an organic material, incineration can greatly reduce or eliminate gas buildup in a repository caused by the radiolysis of organic compounds and bacterial decomposition.[51] Furthermore, the ash from incinerated waste lends itself to immobilization by incorporation with cement into grout or concrete. In addition, incineration as a treatment method has been approved for certain uses by EPA. However, DOE has encountered both technical and regulatory (licensing) problems with some incinerators already constructed. In addition, incinerators unrelated to DOE Weapons Complex activity have been opposed by citizens groups in various communities. As a result, DOE seems to be somewhat wary of incineration as a future waste treatment method.

Table 2-4summarizes the TRU waste incinerators in the Nuclear Weapons Complex. None of these incinerators is currently operational as of late 1990.

According to Benedict et al. (13), ''concentration of burnable solid waste can be very effectively achieved by incineration. The ashes are handled as radioactive waste. This is a rather costly technique because of much effort spent for off-gas filtration and safe handling of the ashes. . . . A much simpler technique is baling of the waste under high pressure. The latter reference is presumably to *compaction* and "supercompactors," discussed below. Unlike incineration, compaction or immobilization in grout or concrete does not destroy hazardous components. Finally, these authors suggest complete decontamination of large, bulky equipment that is contaminated at the surface by rinsing with acids or other solvents, ultrasonic treatment, and sandblasting. There remains, however, the question of what to do with the radioactive solvent or dust generated during decontamination.

Some specific DOE experience with incinerators at Weapons Complex sites designed for use with TRU waste is now reviewed.

[50] Ibid., p. 65.

[51] These two components account for about half of the total gas generated. The rest is the result of metal corrosion.

Table 2-4-Summary of Transuranic Waste Incinerators at DOE Weapons Complex as of July 1990

Site[a]	Name[b]	Type	Start[c]	Feed type[d]	Status
Hanford Plant	WRAP	Plasma arc	1999	T	Planned
INEL	PREPP	Rotary kiln	1985	L, T, R, M	Testing
INEL	WED	Plasma arc	1996	L, T, R, M	Proposed
LANL	CAI	Controlled air	1976	L, T, R, P, M	Standby
Rocky Flats Plant	FBU/PP	Fluidized bed	1974	L, T, R, P	Standby
Rocky Flats Plant	FBU/PROD	Fluidized bed	1978	L, T	Standby
Savannah River Site	PWI	Wire conveyor	1986	T	Standby

a INEL = Idaho National Engineering Laboratory; LANL = Los Alamos National Laboratory.
b WRAP = waste Receiving and Processing Facility; PREPP = Process Experimental pilot plant; WED = Waste Engineering Development Facility; CAI = Controlled Air Incinerator; FBU/PP = Fluidized Bed Unit/Pilot Plant; FBU/PROD = Fluidized Bed Unit/Production; PWI = Plutonium Waste Incinerator.
c Future start dates are estimated.
d Feed type code: L= low-level waste, T= TRU waste: H = high-level waste: R = Resource Conservation and Recovery Act waste: P= Toxic Substances Control Act waste (polychlorinated biphenyls); M = mixed waste."

SOURCE: Office of Technology Assessment, 1991.

The Process Experimental Pilot Plant (PREPP) at the Idaho National Engineering Laboratory (INEL) was ''to demonstrate fill-scale methods for processing the uncertifiable stored TRU waste into a form acceptable at the WIPP [Waste Isolation Pilot Plant]" (28). Rotary kiln incineration is one of several steps that include low-speed shredding and immobilization by cementing.[52] PREPP was built and underwent debugging after some initial tests. DOE had many technical problems with the process, and as of September 1989, PREPP was a year or so away from completion and further testing. The rotary kiln incinerator appears to be primarily responsible for the delays encountered in the startup of PREPP. Both technical and regulatory obstacles must be overcome before operation can begin. In late 1990 it was uncertain when or whether PREPP will become operational.

PREPP has an elaborate off-gas system for the kiln that includes a quencher, venturi scrubber, entrainment eliminator, mist eliminator, reheaters, and HEPA (high-efficiency particulate arrestor) filters.[53] The system is necessary because after final filtration by two banks of HEPA falters, the off-gas will be released from the stack. Hot ash and other inert materials from the kiln will be separated and then grouted with cement in drums.

The Controlled-Air Incinerator (CAI) at Los Alamos has burned both radioactive (TRU) and chemical wastes in an experimental mode and has been modified for future use to burn TRU waste on a continuing operational basis, subject to preparation and approval of an Environmental Impact Statement. The CAI is licensed to burn polychlorinated biphenyls (PCBs) under the Toxic Substances Control Act (TSCA), and in November 1989 received a Resource Conservation and Recovery Act (RCRA) permit to burn hazardous waste. The primary combustion chamber (PCC) of the incinerator can accept up to 125 pounds per hour of solid waste or 200 pounds per hour of liquid waste (32). An elaborate off-gas system is said to reduce radioactive emissions to well below permissible limits under the Clean Air Act.[54] Plutonium throughput is limited because some of the processing vessels do not have the intrinsically safe geometry needed to prevent criticality accidents. No good estimates appear to be available on incineration costs during future operations.

The question of what to do with the ash after incineration is still being explored. Immobilization in cement may not be viable if cadmium or lead is present because the leachability may be too high. One alternative is microwave vitrification of the ash; such a process is being developed in Japan. A regulatory issue still to be resolved concerns some limitations that the State of New Mexico has placed on air emissions, which DOE contends should not be subject to State regulation. Finally, the incinerator at Los Alamos National Laboratory (LANL) has been a source of considerable concern to some members of the community, and certain efforts by LANL to

[52] As an alternative to cementing, research is proceeding on a plasma reactor that could turn waste into unreachable rock. A demonstration test of the plasma reactor is being conducted in Butte, MT under the sponsorship of DOE, the EPA Superfund Innovative Technology Evaluation (SITE) program, and a private company, RETECH; tests were scheduled to be completed by 1991.

[53] Some problems associated with the use of HEPA filters have been described (27).

[54] D. Hutchins, briefing during visit to Los Alamos National Laboratory, Mar. 27, 1990.

win support for the incinerator may have had the opposite effect (23).[55]

Plans for incineration of low-level mixed waste at *Roe@ Flats in a fluidized-bed incinerator* have met with considerable opposition. By 1988, 10 city councils had gone on record as opposing a trial burn with the incinerator, and a lawsuit had halted its use (22). Allegation of illegal use of the incinerator was one element that prompted a 1989 raid by the Federal Bureau of Investigation on Rocky Flats (88). This particular situation is not pursued further here because the incinerator in question is for low-level, not TRU, waste. However, the situation at Rocky Flats illustrates the depth of resistance to be expected when incineration is raised as a treatment option. Also, the residue from incineration, the ash, may well be TRU waste even if the input to the incinerator is not.

Immobilization in Grout or Concrete[56]

The range of products for immobilizing TRU waste is wider than for high-level waste (HLW) because heat generation will be significantly less. Possibilities include glass, cement, bitumen, and polymers. Hydraulic cement has been used for many years.[57] Additives to improve setting properties and fission product retention include sodium silicate. Polymer impregnation of cement is also being developed. Benedict et al. conclude that "in spite of experience, solidification with cement is still an art. Each new waste application must be considered individually because of possible interactions between cement and the waste constituents" (13).

Bitumen, or asphalt, is another possibility. It is "highly leach-resistant, it has good coating properties, and it possesses a certain degree of plasticity" (13). An advantage of bitumen over cement is that it permits almost total removal of water through evaporation, resulting in a volume reduction up to fivefold greater than cement. The disadvantages of bitumen compared to cement include its potential fire hazard and its tendency to release hydrogen and other gases in a radiation environment (13).

For TRU waste of high radioactivity, glass maybe the immobilization medium of choice (13). It has superior radiation stability, and its leach rates are lower than for cement. It is the most expensive choice, followed by bitumen and then cement, but because large-scale vitrification facilities are coming on-line, the marginal cost of immobilizing some TRU waste ash by vitrification, particularly remote-handled TRU waste, might be acceptable. Although TRU waste volumes are large, incineration results in a volume reduction of the order of 100:1 (32).

Current DOE plans for treatment of TRU waste include some immobilization in grout or concrete, although such immobilization is not a general requirement for the acceptance of waste packages at WIPP. Some concerns about immobilization in concrete or grout include the following: What is the longevity of the grout? How long will it retain its structural integrity? How long will it keep the Transuranics, as well as any hazardous components, freed in place and isolated from the environment? What reactions, if any, will take place between the grout and the container?

Compaction

Compaction reduces waste volume by compressing dry solid waste into disposal or shipping containers (18). In general, it has been used more widely in the commercial sector than at DOE sites, primarily for LLW. Supercompaction also appears to be in favor in the European commercial nuclear industry, bringing about LLW volume reduction ratios ranging from 3:1 to 10:1 (36). Recent concerns about storage limits for mixed waste have sparked interest in compaction at DOE.

One limitation of compaction is that the process tends to concentrate radionuclides. Care must be exercised to ensure that the final waste package does not exceed the radioactivity limits of the particular waste category. For TRU waste, there is an upper limit to the radioactivity of waste packages under current WIPP acceptance criteria. Also, plutonium concentrations must not exceed those at which criticality becomes a concern.[58]

[55] Ibid.

[56] Concrete is generally defined as a hard substance made of sand, gravel, cement, and water. Grout is normally defined as a thin mortar used to fill chinks or cracks. Grout, concrete, and "saltstone" are used interchangeably by DOE; sometimes a specific term refers to a particular site. They all refer to products formed by immobilizing waste with cement and various other constituents.

[57] The British are very positive about the use of 'cements, " i.e. concrete. (Source: R. Webster, United Kingdom Atomic Energy Authority, personal communication, Dec. 15, 1989.)

[58] For remote-handled TRU waste, WIPP wrote acceptance criteria limit radioactivity to 23 curies per liter, or about 5,000 curies per 55 gallon drum. Containers are limited to 1,000 plutonium-equivalent curies each, and drums cannot have more than 200 grams of fissile material (69).

A "supercompactor" that received considerable attention in 1989-90 is being readied for operation at Rocky Flats. Because of a limit imposed by the State of Colorado on the *volume* of TRU mixed waste that can be temporarily stored at Rocky Flats, DOE plans to employ compaction in an effort to defer the date on which that limit is exceeded. According to a General Accounting Office (GAO) report, a Rocky Flats official estimated that the supercompactor would reduce by 50 percent the volume of TRU mixed waste generated and stored on-site (44).

The Rocky Flats supercompactor was planned to begin operating in the fall of 1990. However, delays occurred due to both regulatory and technical obstacles. On the technical side, supercompactor components were purchased from several international vendors and had not been tested as a unit. Connection of a glove box to a supercompactor was to be done for the first time; however, the supercompactor press was dropped during shipment from West Germany and found to be rusted, with some electrical wiring vandalized (44). However, DOE reportedly believed that the physical condition of the supercompactor would not be a limiting factor in moving ahead with installation and operation (89). After an environmental assessment (89), a 30-day period of public comment followed. DOE issued a proposed "Finding of No Significant Impact" (FONSI) for construction and operation of the Rocky Flats Supercompactor and Repackaging Facility and the Transuranic Waste Shredder.

In August 1990 it was reported that DOE had approved plans for "a new high-tech waste shredder and compactor" for use at Rocky Flats—presumably the same device described previously. Operation of the device is now planned for early 1991 and is expected to extend Rocky Flats mixed TRU waste storage capacity by up to 18 months if Rocky Flats Plant plutonium processing operations are resumed. The shredder is reported to pulverize graphite molds and falters while the compactor reduces drums of waste to cylinders about 20 inches in diameter and up to 18 inches thick.[59]

The history of the Rocky Flats supercompactor to date would indicate that DOE has not devoted enough resources to the use of this technology at weapons sites. Given the storage situation as it evolved at Rocky Flats, some kind of compaction equipment should have been available or should have been acquired from other DOE sites; evidently, this was not possible.

Shredding and compaction represent the next level of treatment that might be considered as an alternative to the essentially untreated TRU waste packages currently destined for WFP. Treatment costs should be considerably lower than for incineration. Although such treatment would reduce waste volume by a factor of five or so, it might not significantly retard the rate of gas generation; in fact, the shredding and compaction process could conceivably enhance it. Experiments with this waste form are needed.

In Situ Vitrification

A great deal of interest has been generated in the use of in situ vitrification (ISV) as a technology for immobilizing buried waste or contaminated soil. A high current flowing through giant electrodes, in or near the media to be vitrified, melts the material, which then hardens into a glasslike solid. The technique was pioneered at Hanford by Battelle's Pacific Northwest Laboratory with DOE financial support. Battelle then obtained a license for the rights to ISV technology and created the Geosafe Corp. to commercialize the process (24,26). Geosafe's license seems to focus on the use of ISV for hazardous waste sites. Demonstrations at Weapons Complex sites are being carried out by DOE and its contractors.[60]

The advantages of ISV include vitrification of soils up to a depth of 30 feet, destruction of organics and incorporation of heavy metals into the vitrified mass, complete dissolution of cement inclusions within the vitrified mass, and more modest off-gas system requirements than incineration.[61] Perhaps the greatest potential advantage is the prospect of immobilizing buried waste, thereby eliminating the need or cost of exhumation, treatment, transport, and disposal, as well as the health risk to workers involved in these operations. Some consideration is also being given to immobilizing drum and tank waste by using ISV (24).

[59] "DOE Approves Plan for Waste Compactor at Rocky Flats," Associated Press News Release, Aug. 16, 1990.

[60] Koegler, S., Battelle Pacific Northwest Laboratory, remarks at Office of Technology Assessment Workshop on Soils and GroundwaterRemediation Technologies, May 8, 1990.

[61] Ibid.

Areas requiring further investigation include the economics and possible safety or health hazard from ISV. According to DOE personnel, in situ vitrification requires relatively dry soil and energy costs of 1.5 to 2 cents per kilowatt-hour, to be economically feasible.[62] A cost of about $250 to $350 per ton is estimated for most vitrification operations (24). Unanswered health and safety questions include performance of the off-gas system and possible worker hazards from strong electric fields.

The first full-scale test of in situ vitrification of mixed waste is underway at Hanford. During April 1990, researchers intended to melt in place the contents of a waste crib and the soil surrounding the crib in the 1OO-B area, a high-priority site for cleanup under the Hanford tri-party agreement. After the 9-day test, about a year would be required for the molten waste to harden into an 800-ton mass (28).

preliminary results of the Hanford mixed waste ISV test were reported at a May 1990 Office of Technology Assessment (OTA) workshop.[63] Although plans were to meltdown to a depth of 20 feet, the test was halted at a depth of 14 feet because of concern that the horizontal spread of the melt would exceed the limits of the hood that collects off-gases. Roughly 75 percent of the hazardous materials in the waste crib and 50 percent of the radioactive materials in the crib were reached. The full-scale demonstration used three semitrailers and is capable of melting 3 to 5 tons per hour. In this mixed waste test, the radionuclides were strontium and cesium. An earlier full-scale test was performed about 2 years ago on a trench in which plutonium solutions had been dumped. That test reached a depth of 15 feet.

The ISV mixed waste test cost about $1.8 million, with about one-third of that needed for environmental documentation and characterization.[64] The cost of the 9-day melt period was estimated at about $250,000. Total costs to date for the development of in situ vitrification are on the order of $10 million.

The following evaluation of ISV was offered at the May 1990 OTA workshop: It is effective near the surface and ready for use on radionuclides and heavy metals in shallow land burial sites. Hopefully, in a few years, it will be available for use on Hanford single-shell tanks,[65] after they are fried with soil. The grasslike product is more leach resistant than the melt from the HLW vitrification process because melt temperatures are higher. Some limitations include the depth to which a melt can be carried out and the water or moisture content of the soil; high moisture content increases the energy costs. ISV should be roughly comparable in cost to exhumation and treatment, and should be very effective on tough mixtures. Furthermore, it minimizes worker radiation exposure compared with removal and treatment of the waste. However, ISV is not a solution for all the buried waste and contaminated soil at all DOE sites. It should be applied selectively to the worst "hot spots."

Some issues discussed, but not necessarily resolved, at the OTA workshop were the following: How good are the off-gas systems used in connection with in situ vitrification? Can the ISV process lead to further contamination outside the melt zone? Is ISV likely to be acceptable to local communities and citizens who may expect to have the waste physically removed? What are the prospects for ISV now that the Geosafe process has been accepted in the Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) program?

In October 1989, the first INEL field test of in situ vitrification was carried out. This test, which was on a scale about one-tenth that of Hanford,[66] involved movable electrodes, an off-gas containment hood made of fabric rather than metal so that equipment could be transported by truck, and simulated TRU waste with high buried metal content and high buried combustible content, but without radioactivity. Below the electrodes were both stacked drums and randomly dumped drums and boxes of waste.[67] This intermediate-scale ISV test was aborted be-

62 L. Duffy, U.S. Department of Energy, remarks at special meeting of OTA Advisory Panel, Mar. 1, 1990.

63 S. Koegler, op. cit., footnote 10.

64 Ibid.

65 In September 1990, Battelle Pacific Northwest Laboratories began what was described as the "first field test to collect data to determine whether ISV can effectively be used on tanks and their contents." The tank contained hazardous waste but no radioactive component. (See "PNL Halts In Situ Vitrification Test on Mock Tank Containing Wastes," *Report on Defense Plant Wastes,* Sept. 14, 1990.)

66 Ibid.

67 J.L. Landon, "In Situ Vitrification Update," presentation to National Academy of Sciences Panel on Buried Wastes a INEL, Nov. 13-14, 1989.

cause the fabric hood was ''glowing' and flames were present. Simulated waste buried deeper than 24 inches showed no evidence of heat damage, and glass splatter around the melt zone was uneven.[68] After review of the system and revision of procedures and equipment, a second test was reported to have been completed successfully in 1990, with a metal rather than a fabric hood.

The Applied Research, Development, Demonstration, Testing, and Evaluation Plan (RDDT&E)

The draft DOE RDDT&E plan of November 1989 singles out three specific needs' to overcome problems in TRU waste management, in addition to opening WIPP for its 5-year demonstration period. These include the need for "better TRU waste treatment to meet WIPP certification requirements,' "better characterization of RCRA components in TRU waste for certification,' and 'disposal options for TRU waste not certifiable for WIPP" (47).

In the area of TRU waste treatment, wastes for which treatments must be demonstrated include "resins and sludges that release water during storage, organic waste forms that generate excessive gas, and reactive metals such as sodium and sodium/potassium mixtures. ' Technologies of interest to DOE for treating noncertifiable TRU waste include ''microwave melting, plasma decomposition, smelting, denigration, dehalogenation, incineration with the resulting ash solidified by cementation or in-can melting, and chemical oxidation by nitrate salts' (48). Concreting or grouting and reactive metal neutralization are also of interest,

In the characterization area, the DOE RDDT&E plan indicates that technologies are needed to better characterize the containers of stored TRU waste, which can be found at most sites, for their hazardous RCRA components, as well as to determine which are and which are not TRU waste. According to the report, the ''technologies to be used in this area have not been identified'; DOE is in the review and survey stage (49) (see figure 2-10).

Waste that is noncertifiable for WIPP will have to be disposed of elsewhere in other ways; such waste includes oversized packages, large pieces of equipment, waste containing high explosives, and certain classified waste. DOE is working on a technology called Greater Confinement Disposal (GCD) at the Nevada Test Site (NTS); this involves placement in a deep hole, as an alternative to WIPP disposal for noncertifiable TRU waste. GCD has been used at Savannah River and Oak Ridge for someGreater-than-Class C LLW (50). It has been undergoing evaluation at NTS with the goal of compliance with EPA standards (40 CFR 191) for management and disposal of HLW and TRU waste (50).

The RDDT&E plan focuses explicitly on some aspects of TRU waste management for retrievable stored waste; research and development for buried TRU waste are addressed indirectly. For example, although buried TRU waste at Idaho is mentioned as an example of a particular problem to be solved (51), it is not singled out as a distinct category. Nevertheless, buried waste will clearly benefit from research on the "Problems in Remediating Contaminated Soils," which is part of the plan (52).

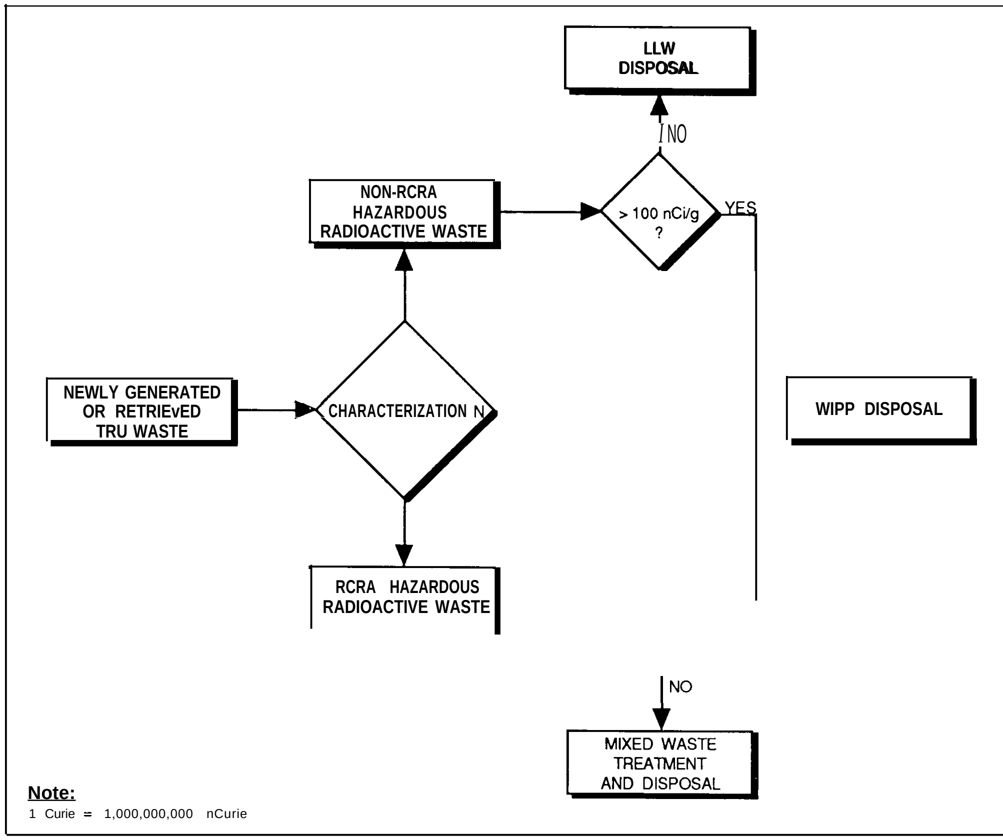
One aspect that needs more work is setting priorities for technologies that might be useful rather than simply listing them. There is little information in either the 1989 RDDT&E plan or the 1990 Five-Year Plan that would help distinguish between what is being funded and what is not. Also WIPP is considered to be outside these plans because it has already been built and a 5-year demonstration phase is planned. Nevertheless, research is needed on gas generation in alternative TRU waste forms for WIPP, as well as on aspects of the interaction between waste and the surrounding WIPP medium.

Actinide Conversion (Transmutation)

The idea of separating out the actinide elements (uranium plus the Transuranics) from high-level waste created from spent fuel in commercial nuclear reactors and of recycling the actinides to a reactor has been considered for some time. Removal of actinides from the waste could conceivably remove a significant portion of the long-lived radioactive hazard; putting the actinides back in a nuclear reactor or accelerator can result in a reduction of their radioactivity as a result of fission or conversion

[68] Ibid.

Figure 2-10-Characterization of Transuranic Waste To Determine Disposal Option



SOURCE: U.S. Department of Energy, "Applied Research, Development, Demonstration, Testing and Evaluation Plan," Draft, 1989.

(transmutation)[69] to shorter lived isotopes. However, as Benedict et al. point out in a 1981 book, (14) "The reduction of the ingestion hazard after recycling equilibrium has been reached will be only modest, and the technical effort will be enormous. The technology for actinide partitioning is not available as yet, and considerable development will be required to make it available. Moreover, it has to be considered that part of the actinides are transferred from the waste to the fuel cycle on recycling, where they may create an even greater hazard than the waste. "

Although these authors are skeptical about the benefits of actinide separation for high-level waste, they are more optimistic about treating TRU waste in this manner. They point out that for some forms of TRU waste, actinide recovery could appreciably reduce the ingestion hazard of the waste because of the relatively low fission product concentration compared to high-level waste.[70] Furthermore, it should be simpler technically to accomplish this for TRU waste than for high-level waste (15).

A more recent (1989) analysis of actinide conversion by Rockwell International is somewhat more positive. The Rockwell authors believe that whereas aqueous reprocessing does not lend itself well to

[69]The terms *transmutation and partitioning*, or just *transmutation*, *are* often used to characterize what we have called *actinide* conversion. Transmutation involves converting one chemical element or isotope into another by a nuclear reaction. In principle, long-lived radioisotopes in nuclear wastes could absorb neutrons in a fission reactor or a future fusion reactor and be converted into short-lived or stable isotopes, A practical system would need to be capable of separating or partitioning isotopes in a special reprocessing system, and fabricating the long-lived ones into a form for further irradiation. (See R.L. Murray, Understanding Radioactive Waste, 3d cd., Batelle Press, 1989, p. 123.)

[70]Presumably this analysis also holds for inhalation hazards, the principal concern about alpha-emitting radionuclides such as plutonium.

actinide conversional the development of a new concept involving pyrometallurgical processing of fuel from a metallic fast reactor could ultimately yield economic benefits, compared to the disposal of spent fuel in the commercial sector. In addition, according to the Rockwell report, risks due to accidents or environmental contamination would be reduced. In the Rockwell concept, not only are ''minor actinides" (i.e., nonplutonium actinides) reduced at the rate of about 5 percent per year in a dedicated facility for that purpose, but technetium-99, a long-lived radionuclide that tends to follow LLW, is also transmuted to shorter-lived radionuclides after separation and return to a reactor. Separated strontium-90 and cesium- 137 are handled by allowing them to decay for a hundred years or so rather than transmuting them or putting them in a facility for 10,000-year waste *(39).*

Although the Rockwell concept is directed primarily at the commercial sector, it might apply to the defense sector. In the latter, reprocessing to recover plutonium is an accepted practice and major goal, in contrast to the commercial sector where concern about the proliferation of plutonium has been a factor in the United States not encouraging such activity. In many ways, a facility that permits partitioning of the waste and transmutation of certain targeted radionuclides, which will drastically reduce the long-lived radionuclide population, is an appealing concept. Additional research in this direction could well be valuable, particularly if long delays in repository opening persist.[72] However, the integrated fast reactor and pyrometallurgical fuel processing facility are far from functional realities and would require the development of an entirely new nuclear fuel cycle. Both pyroprocessing and an aqueous process known as Thorex are being worked on by two different groups at Argonne National Laboratory. Each must contend with the fact that only a fraction of the TRU radionuclides loaded into a reactor is transmuted in a given cycle.

At least a decade or two will probably be required before actinide conversion becomes a practical possibility and the costs could be high.[73] Thus, in the short run, actinide conversion does not appear to be a significant factor in high-level or TRU waste management.[74] Nevertheless, converting TRU elements in tank waste to useful elements through a new ''waste burn" technology is one of the rationales put forward in a Westinghouse report to prevent DOE from eliminating funding for the Fast Flux Test Facility (92).

Waste Minimization

One element of the RDDT&E plan involves research on the minimization of waste from plutonium manufacturing and processing. TRU and byproduct waste are generated by all plutonium-related operations, including raw materials, component manufacture, scrap reprocessing, or reclamation. Currently, typical reprocessing of plutonium oxides and scrap is performed pyrochemically or via aqueous methods involving nitric or hydrochloric acid. Research is striving to improve plutonium yields, reduce the quantities of scrap, reduce waste and processing of byproducts, and reduce hazardous chemicals and the amount of mixed waste. Among the opportunities for minimization listed by DOE are forming blanks closer to final size, improving the precision of machining operations, using robotics and automation in handling operations, and improving plutonium recovery by employing fewer chemicals and producing less plutonium-bearing waste (53).

Research and development on the minimization of waste from plutonium manufacturing and processing could yield real benefits, in terms of reducing both the amount of waste to be treated or disposed of and the safety and health threats to workers. It should be vigorously pursued.[75]

[71] By contrast, it has been stated elsewhere that separation by pyroprocessing is not as good as aqueous processing. Source: L. Lidsky, Professor of Nuclear Engineering, Massachusetts Institute of Technology, personal communication, Apr. 30, 1990.

[72] The Japanese are reported to be moving ahead with a 10-year research effort, the Omega program, to create a system to transmute radioactive nuclides in spent fuel using proton and electron accelerators. (See Nuclear Waste News, Nov. 29, 1990, p. 467.)

[73] This view is supported by Lidsky, who believes that 10 years from now, actinide conversion would not be a reality; he views it more as a technology of last resort. Source: (Lidsky, L., op. cit., footnote *20.)*

[74] This view is supported by a March 1990 statement by the Radioactive Waste Management Committee Bureau of the Organization fOr Economic Cooperation and Development/Nuclear Energy Agency.

[75] There is some indication of forward movement in this regard at DOE. At the February 1991 Waste Management Conference in Tucson, AZ, it was announced that DOE had reallocated 25 percent of its FY 1990 process developmetn funds, some $44 million, to waste minimization R&D. The fraction allocated to TRU waste minimization was not indicated.

THE REGULATORY FRAMEWORK

Introduction

The regulatory framework for TRU waste is a complicated one. There are some similarities between regulation of TRU and high-level waste and some differences. TRU waste, as a distinct category, was not formally defined until 1974, when the U.S. Atomic Energy Commission (AEC) proposed new radiation protection standards in the *Federal Register (20);* prior to that, it had not been distinguished from LLW. The current definition of TRU waste both in a Department of Energy (DOE) order and as codified by the Environmental Protection Agency (EPA), is quite quantitative and specific. It also differs from the earlier definition in that the previous lower radioactivity limit of 10 nanocuries per gram has been increased by a factor of ten.

TRU waste is generated, buried, or stored at a number of DOE Weapons Complex sites. Plans call for stored and newly generated waste to be treated, certified, and transported to the Waste Isolation Pilot Plant (WIPP) for disposal. Thus, as many as 22 States in addition to the Federal Government have a regulatory stake in the management of TRU waste within or moving through their boundaries. In addition, much TRU waste is mixed waste.[76] Whereas much high-level waste (HLW) is also mixed waste, in tie latter case the relative hazards are believed to be such that safe handling of the radioactive component will in many instances ensure safe handling of the hazardous component. For some TRU waste, however, the hazardous component may assume more importance. The regulatory framework thus encompasses a wide spectrum of elements—DOE orders; EPA and NRC standards; and various agreements among Federal, State, and other parties.

Although the Nuclear Regulatory Commission was given regulatory authority over civilian nuclear power, its role in connection with defense sites is very limited. Because TRU waste is almost exclusively a product of defense activity, DOE, through the mechanism of DOE orders that are not codified, retains considerable regulatory authority over its own activities.

Definition of Transuranic Waste

In Nuclear *Imperatives and Public Trust: Dealing With Radioactive Waste,* L. Carter provides some historical background concerning the definition of TRU waste. Evidently, TRU waste was not explicitly defined until 1974 when the Atomic Energy Commission proposed a rule (10 CFR Parts 20 and 50) defining TRU waste as any material with 10 nanocuries of TRU radionuclides per gram (20). Carter cites this proposed regulation as one of a series of events that worked against the development of a commercial reprocessing facility at Barnwell, SC: “TO establish this threshold, at a level almost too low to be measured, meant that large amounts of general-process trash at Barnwell. which otherwise might have been regarded as ordinary LLW and disposed of as such, now would have to be kept in retrievable storage and eventually shipped to a geologic repository” (20). Carter points out that the proposed rule never took effect and was superseded by NRC regulations in 1982 setting the lower limit for TRU waste at 100 nanocuries per gram. By that time, the Barnwell Plant had been abandoned, in part due to U.S. concerns about plutonium proliferation.

The new definition places TRU waste somewhere in between HLW and LLW.[77] However, at the upper end of the TRU waste definition, there appears to be no clear demarcation between TRU and high-level waste. The concentration of Transuranics in Hanford soil is reported to be as high as 40,000 nanocuries per gram on the surface (22). According to current waste acceptance criteria, remote-handled TRU waste containers with surface dose rates as high as 1,000 rem per hour may be shipped to WIPP (72), equaling or exceeding the surface dose rates estimated for some defense high-level waste canisters.

A meeting that appears to have been instrumental in changing the definition of TRU waste took place at Gaithersburg, MD, in August 1982. Representatives of the program committee for that Workshop on Management of Alpha-Contaminated Waste were, with the exception of one EPA representative,

[76] This is illustrated by the fact that 62 percent of all retrievable stored TRU waste through 1988 was at the Idaho National Engineering Laboratory (INEL) and, of this, approximately 95 percent was suspected to be mixed waste. (See J. Solecki, ''INEL Waste Management,'' viewgraph C8 4870, 1989.) A somewhat lower percentage, 40 percent, of all TRU waste stored at eight sites managed by DOE Albuquerque operations (excluding INEL and Rocky Flats) is estimated to be mixed waste as of December 31, 1989. (See R. Ortiz, U.S. Department of Energy Albuquerque Operations Office, personal communication to P. Johnson, Apr. 10, 1990.)

[77] In the mid-1980s, an effort was made t. revise the definitions of high-level, TRU, and low-level wastes but to no avail. For a useful discussion, see the report by Kocher and Croff (29).

all DOE employees or contractors. The program committee concluded that ''a level of 100 nCi [nanocuries] of long-lived alpha contamination per gram of waste, averaged over the contents of a waste package, can be designated as a concentration of long-lived alpha-emitting radionuclides in LLW destined for near surface disposal that is unlikely to result in exceeding present dose limits' (13). In 1984, EPA codified this result in the *Federal Register* by making 100 nanocuries per gram the lower limit for the definition of TRU waste. Evidently, there were no objections during the public comment period.

The impetus for changing the lower bound of the TRU waste definition from 10 to 100 nanocuries per gram could have been due to a variety of factors. Improvements in assay techniques were making it possible to measure Transuranics down to the 100 nCi/gm level. If it is easier and cheaper to dispose of LLW than TRU waste, the lower bound has considerable economic importance. It could affect such matters as how much cleanup must be done on pre-1970 buried waste at defense sites and how much must be packaged to go to WIPP. Thus, costs and benefits must be considered. It has been estimated that the redefinition of TRU waste served to reduce the volume of plutonium-contaminated soil at Hanford from 400 million to 100 million cubic feet. The redefined 300 million cubic feet would then be subject to less stringent cleanup standards, thus reducing the cost but increasing the risk.

The draft Environmental Impact Statement (EIS) by EPA for disposal standards for TRU and high-level waste (40 CFR 191) that was remanded by a court seems to treat TRU waste as a corollary to high-level waste: "The proposed standards [for spent fuel and high-level waste] also apply to wastes containing alpha-emitting TRU nuclides with half-lives greater than 1 year[78] at concentrations greater than 100 nanocuries per gram" (87). After pointing out that alpha-emitting TRU nuclides constitute a special type of hazard because of their long half-lives and high radioactivity, the draft EIS cites two or three studies that provide some guidance as to what the concentration level at the interface between TRU and LLW might be and concludes that TRU waste with concentrations higher than 100 nanocuries per gram should be included under EPA standards. However, the scientific evidence does not appear convincing. Based on the same data, a different lower limit (i.e., 10 nanocuries per gram) could have been defined.

A definition is not a safety standard. The grouping of TRU waste with high-level waste in developing EPA disposal standards indicates that these two wastes have something in common that requires somewhat similar disposal. TRU waste, unlike LLW, is supposed to be placed in a repository rather than disposed of at or near the surface. This is consistent with DOE and predecessor agency policy back to the 1970s when the WIPP idea originated. However, regardless of the definition, waste--whatever the category-must meet certain disposal standards that, according to the present system, are determined by the radiation dose and the risk to individuals under a variety of scenarios.

Regulations Affecting Transuranic Waste

Buried Waste

At a National Academy of Sciences meeting on buried TRU waste at the Idaho National Engineering Laboratory (INEL), the principal DOE contractor, EG&G-Idaho, described the risk and performance assessment work underway concerning alternative methods of dealing with buried TRU waste in the Subsurface Disposal Area (SDA) at INEL. A summary of the approach follows.[79]

Because of the mixed nature of the waste, both health-based risk assessments concentrating on short-lived effects and performance assessments focusing on long-term risks must be considered. Health-based risk assessments conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) involve identification of contaminants, exposure assessment, toxicity assessment, and risk characterization.[80] The health-based risk assessment at the SDA is currently in the early stages, as part of the Remedial Investigation/Feasibility Study (RI/FS) process. Performance assessment at an existing burial site raises many questions: What requirements apply? What intrusion scenarios should be considered? What siting

[78] The half-life limit was changed to 20 years in the ''final'' standard.

[79] R.R. Piscitella, EG&G I&&~, ''Overview of Risk/Performance Assessment,'' presentation with viewgraphs made to the National Academy Of Sciences Panel to Review the DOE Assessment of Pre-1970 Buried Waste at the Idaho National Engineering Laboratory, November 1989.

[80] 42 U. S.C.A. §§6904(i)(6)(A)-(F) (West Supp. 1990).

criteria apply? What waste acceptance criteria apply? What type of data are needed?

A problem associated with EG&G's SDA performance assessment concerns the lack of appropriate regulations for old burial sites. EG&G's approach, as presented at the National Academy of Sciences panel meeting, was to apply regulations for new geologic disposal sites to the old burial sites, as illustrated by table 2-5. EG&G concluded that "performance assessment will require using applicable parts of regulations that were written for new disposal sites" and that "DOE orders, CFRs, and other ARARs [applicable or relevant and appropriate requirements] that apply to SDA risk assessments will be identified in the RI/FS work plan. ''[81] However, some members of the panel objected to applying EPA regulations for new deep repository sites (40 CFR 191) to the old shallow land burial sites. Furthermore, the regulations for repositories have been remanded by a court and must be reissued.

In November 1989, INEL was placed on the National Priorities List (NPL) under CERCLA.[82] Some work on risk assessments was underway during 1990 on certain remedial actions associated with buried TRU waste, namely, retrieval of the waste, vapor vacuum extraction of subsurface organic vapors, and in situ vitrification.[83] Furthermore, alternative strategies for remediating the buried TRU waste have not yet been thoroughly evaluated.[84]

Table 2-5--Potential ARARs for Assessment of Buried Waste at the Subsurface Disposal Area at INEL

Applicable or Relevant and Appropriate Requirements (ARARs)	Source
1. For 1,000 years of groundwater protection . 15 picocuries/liter of alpha-emitting radionuclides . Beta or gamma radiation, annual dose equivalent 4 millirems	40 CFR 191
2. For 1,000 years of human protection-all pathways annual dose equivalent • 25 millirems whole body • 75 millirems critical organ	40 CFR 191/ 10 CFR 61
3. For 10,000 years to have less than one chance in 10 of exceeding limits defined in this CFR	40 CFR 191
For 10,000 years to have less than one chance in 1,000 of exceeding 10 times the limits defined in this CFR	40 CFR 191
4. For protection from inadvertent intrusion at any time after institutional control	10 CFR 61
5. To maintain radioactive exposures as low as reasonably achievable (ALARA)	10 CFR 61

SOURCE: Adapted from J. Solecki, "INEL Waste Management, "viewgraph C8 4870, 1989.

Waste Storage

The rules applicable to TRU waste storage encompass the following: EPA regulations governing the hazardous component of the mixed TRU waste (particularly those referred to as land-ban restrictions), State imposed restrictions (e.g., the decision by the Governor of Idaho not to accept any more Rocky Flats waste and the decision by the Governor of Colorado to limit the volume of mixed TRU waste that can be stored at Rocky Flats), DOE orders (particularly those dealing with purely radioactive materials), and requirements of Federal Facility Agreements, Consent Orders and interagency agreements involving EPA, DOE, and State agencies.

EPA land disposal restrictions for hazardous and radioactive mixed waste generally prohibit or ban the storage or disposal of hazardous waste unless it is treated according to EPA-approved methods. At present, there is a 2-year variance from these restrictions, due to a lack of treatment capacity. Since much TRU waste is mixed waste (i.e., it has both hazardous and radioactive components), it is generally covered by the present variance from the land ban rules.[85]

Certification and Transport of Waste to the Waste Isolation Pilot Plant

According to the DOE 1989 Five-Year Plan, ''The Waste Acceptance Criteria Certification Com-

[81] Ibid., viewgraph 9-10174.

[82] W.N. Sate, U.S. Department of Energy, viewgraph E90-0636 at National Academy of Sciences Panel Meeting On Buried TRU Waste at Idaho, Mar. 20-21, 1990.

[83] R.R. Piscitella, presentation at National Academy of Sciences Panel Meeting on BurieTRU Waste at Idaho, Mar. 20-21, 1990.

[84] In analyzing alternatives for remediating buried Wrote at INEL, historical and Political factors must be considered. According to a DOE presentation made to the OTA project team during a visit to INEL in 1989, commitments were made on three separate occasions, twice in 1970 and once in 1973, by AEC officials to remove buried waste from Idaho. (See Solecki, J., ''INEL Waste Management," Viewgraph c9 0084, 1989.)

[85] In June 1990, recognizing lack of treatment capacity nationwide, EPA issued a 2-year variance from the mixed waste land disposal regulations. An extension to this variance of up to 1 year, which maybe extended for an additional year, can also be obtained upon request on a case-by-case basis. (See Land Disposal Restrictions for Third Thirds Schedule Wastes, 44 F.R. 22320,22644 (1990); and Procedures for Case-by-Case Extensions to an Effective Date, CFR §268.5 (1989).)

mittee (WACCC), consisting of representatives from EPA, the State of New Mexico, and DOE, negotiated and established stringent criteria on the form of waste acceptable at the Waste Isolation Pilot Plant" (60). However, this statement is contradicted in the WIPP Supplemental EIS. The latter document says that the Waste Acceptance Criteria (WAC) for WIPP were "developed by a DOE-wide committee of experts. . . ." Furthermore, the WACCC was established in 1979, prior to EPA becoming involved in WIPP (31). The role of a more broadly based WACCC, involving groups outside DOE, seems to be limited primarily to ensuring compliance with the acceptance criteria that DOE established (73). For example, even though EEG has participated on audit teams in certification reviews, their review can be accepted or rejected by DOE.[86] This situation could be significant, if outside parties seek to influence the outcome of the debate about modifying the waste form for WIPP.

According to the 1989 Five-Year Plan, DOE shipments of radioactive material are regulated primarily by the Department of Transportation and the NRC; EPA and the Interstate Commerce Commission also have regulatory roles. DOE also indicates that it abides by State, Indian tribal, and local regulations ''consistent with Federal requirements. Regulations cover design and testing of the transport package; shipment identification including labeling, marking, placarding, and preparing shipping papers; package and vehicle inspections; and routing and driver training for spent fuel and high-level waste" (63).

In 1989, the NRC approved the TRUPACT-II container design for use in shipping contact-handled TRU waste to WFP. However, beginning late in September 1989 and continuing into the first half of 1990, the NRC found a variety of manufacturing defects in the initial 15 TRUPACT-II containers during routine inspections which led the NRC to notify DOE and the manufacturer, the Nuclear Packaging Division of Pacific Nuclear Corporation (NUPAC), of noncompliance. An NRC inspection in late August 1990 of six new TRUPACT-II units in various stages of completion revealed that the units and manufacturing processes were inadequate. It is alleged that earlier, NUPAC had filed a request to the NRC "on behalf of the Department of Energy" to amend the specifications in the standards for the dimensions of the containers so that the 15 original containers manufactured by NUPAC would be acceptable; NRC turned down NUPAC's petition.[87]

The issue of safe transportation of waste to WIPP will undoubtedly continue to be an area of technical and public concern.

Regulations Affecting the Waste Isolation Pilot Plant

The function of WIPP, as set forth in the Department of Energy National Security and Military Applications of Nuclear Energy Act of 1980 (Public Law 96-164), is to serve "as a defense activity of the Department of Energy. . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive waste resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission" (64). From the outset, certain oversight activities were established through legislation. The original legislation authorizing WIPP requires that the Secretary of Energy consult and cooperate with appropriate officials of the State of New Mexico concerning health and safety concerns and that a written agreement be entered into by the two parties specifying procedures for such cooperation and consultation. That agreement has been rnodified several times since its enactment (69).

DOE must comply with a variety of Federal requirements applicable to WIPP, including the National Environmental Policy Act (NEPA), RCRA, and EPA disposal standards for TRU waste (69). Under NEPA, a Record of Decision must be issued by the Secretary of Energy subsequent to having received comments on the Supplemental Environmental Impact Statement. Under RCRA provisions, DOE must show, in a "no-migration" petition to EPA, that the hazardous component of the waste to be placed in WIPP will not migrate. DOE must also demonstrate that radioactive materials in the repository will conform to EPA disposal standards (40 CFR 191) for TRU waste.[88] These standards are

[86] R. Neill, Environmental Evaluation Group, personal communication, June 29, 1990.

[87] *Weapons Complex Monitor,* Sept. 17, 1990, pp. 19-20.

[88] There is an important distinction between DOE demonstrating compliance with EPA disposal standards for radioactivity and EPA-RCRA standards for migration of hazardous waste. In the latter case, EPA determines whether DOE has complied, whereas for radioactivity, DOE determines compliance, i.e., self-compliance.

being reformulated by EPA after having been remanded by the 1st Circuit Court of Appeals in Boston because they allowed higher levels of radionuclide contamination of drinking water than in the Safe Drinking Water Act.[89]

In September 1990, the Board of Radioactive Waste Management of the National Research Council (BRWM) convened a Symposium on Radioactive Waste Repository Licensing in response to "widespread scientific concern and interest in the revisions being made during the remand of 40 CFR Part 191."[90] Among those concerns was a recommendation expressed to the chairman of the NRC by the Commission's Advisory Committee on Nuclear Waste, that:

> . . . the Commission object to the EPA standards on the basis that
>
> —There are no obvious ways for demonstrating compliance of any specific repository site with the Standards. In this sense, the Standards may be unrealistic.
>
> —The Standards are also overly stringent and inconsistent. There is strong evidence that they will be wasteful of resources with little commensurate interest.[91]

The BRWM convened the Symposium shortly after issuing a position statement entitled "Rethinking High-Level Radioactive Waste Disposal."[92] That statement indicates that, given what the BRWM characterizes as the current highly inflexible U.S. technical approach to high-level waste disposal coupled with the U.S. regulatory approach, it is unlikely that effort will succeed. The BRWM proposes an alternative approach that they believe will "require significant changes in laws and regulations, as well as in program management."[93] Although the BRWM statement focuses on high-level waste disposal, its analysis of regulations and standards is relevant to TRU waste disposal.

At the symposium, the Environmental Evaluation Group (EEG) defended the current approach being used by EPA in setting the disposal standard as follows:

> Reasonable confidence in the prediction of site behavior for 10,000 years or more is achievable using well-established principles of geosciences. EPA's approach of probabilistic release limits with flexibility in the implementation of the Standard is a sound one. EEG believes that the numerical basis of the Standard is set at a level that is reasonably achievable for a good site that is properly engineered, and should not be significantly relaxed.[94]

In arriving at this conclusion, EEG pointed out that any drastic change from the 1985 (remanded) standard might delay the issuance of a final standard for several years, causing uncertainties at WIPP. In addition, if the new Standard were to differ significantly from the remanded one, it would greatly increase the probability of a remand of the new standard.[95]

A distinction has developed between the regulatory compliance required for a fully operational WIPP facility and that required for an initial set of experiments in WIPP. On November 14, 1990, EPA published its decision to rule in favor of DOE's no-migration petition, conditional upon DOE activity being limited to an initial test phase.[96] EPA thus will allow DOE to emplace waste in WIPP for the test phase without demonstrating that ultimate disposal standards will be met. The decision is justified by the research nature of the experiments and the fact that the waste will be retrievable, if necessary, during and immediately after the test phase. However, in so doing, EPA is allowing a different path to be taken for WIPP than for the high-level waste repository; in the latter, current policy is that construction cannot begin until compliance with long-term disposal standards is demonstrated.

89 "EPA Waste Regulation Comes Under Fire at National Research Council Meeting," *Nuclear Waste News*, Sept. 20, 1990, p. 366.

90 Letter from Frank L. Parker, BRWM, to John H. Gibbons, OTA, Aug. 22, 1990.

91 Ibid., p. 1.

92 National Academy of Sciences, "Rethinking High-Level Radioactive Waste Disposal: A Position Statement of the Board on Radioactive Waste Management" (Washington DC: National Academy Press, 1990).

93 Ibid., p. 5.

94 R.H. Neill, J.K. Channell, and L. Chaturvedi, "New Mexico Environmental Evaluation Group Perspective on Transuranic and High-Level Waste Disposal Regulations," paper presented at Symposium on Radioactive Waste Repository Licensing, Board on Radioactive Waste Management, Washington, DC, Sept. 17-18, 1990, p. 2.

95 Ibid., p. 11.

96 Conditional No-Migration Determination for the Department of Energy Waste Isolation Pilot Plant (WIPP), 55 Fed. Reg. 47700 (1990).

In an October 1989 briefing by DOE about its plans for WIPP, the decision of whether to move ahead with the test phase was asserted to be the prerogative of the Secretary of Energy. In the DOE presentation, three categories of action were listed as being necessary to move forward: technical internal actions for which approval rests within DOE; technical external actions for which approval or comment resolution is required from external organizations such as EPA or EEG; and "institutional" issues (58). DOE has since focused considerable attention on the latter category in order to keep the WIPP program moving forward according to their plans. For example, once the conditional no-migration petition was issued by EPA, the biggest remaining obstacle to placing the first experimental waste package in WIPP was accomplishing land withdrawal. Since Congress did not proceed to enact land withdrawal legislation, DOE obtained the necessary land administratively in early 1991. Thus, although there are some checks and balances, the WIPP project remains to a considerable extent under the control of the Department of Energy.

DISCUSSION

Definition of, and Standards for, Disposal of Transuranic Waste

The change in the early 1980s of the lower limit in the definition of TRU waste from 10 to 100 nanocuries per gram of alpha radioactivity allowed more waste to be classified and treated as LLW. This shift, given current disposal practice and plans that call for LLW to be disposed of at or near the surface (whereas TRU waste requires deep geologic repository disposal), is expected to result in tens or hundreds of millions of dollars in savings. However, irrespective of definition, the waste, whatever its classification, must satisfy the standards set for its disposal.

The Environmental Protection Agency (EPA) is in the process of reissuing disposal standards for spent fuel, high-level waste (HLW), and TRU (40 CFR 191); as a result of a lawsuit by several States and environmental groups, an earlier version of the standards was found wanting by the First Circuit Court, Boston, and remanded.[97] A second working draft of the revised standards was issued for comment in 1990. When promulgated, these standards will apply to the Waste Isolation Pilot Plant (WIPP) if and when it becomes operational as a disposal repository for TRU waste. These standards will be subject to debate, both within the technical community and the public at large. Among the issues that might be debated are the length of time that the waste must be isolated from the environment and the desirability of being able to retrieve the waste at some future date.

Repository Delays; Alternative Storage and Disposal Strategies

Retrievable stored TRU waste at Department of Energy (DOE) sites is located at 10 Weapons Complex sites, generally as loosely packed material in 55-gallon drums stored at or near the surface. The nominal design lifetime of the drums is about 20 years; some have already reached that limit. Current plans call for TRU waste to be shipped to a deep geologic repository for disposal in a form not very different from its current form. The only possible repository available for the stored waste is the Waste Isolation Pilot Plant near Carlsbad, NM. Construction of WIPP is essentially complete. As of early 1991, however, no experiments have yet been performed involving placement of waste in the facility to aid in determining if WIPP is a suitable facility for long-term disposal of TRU waste. In addition, even if the earliest date-1995-for opening WIPP on an operational basis is achieved, it will take 25 to 30 years to fill the facility with currently stored and yet-to-be generated TRU waste.

There is thus a need to identify other alternatives for short-, intermediate- and long-term storage of TRU waste. In the short term, DOE is confronted with the mixed TRU waste that has been accumulating at the Rocky Flats Plant since September 1989 when the Governor of Idaho refused to allow further shipments to the Idaho National Engineering Laboratory (INEL). Although the start-up of a supercompactor in 1991 may ease the situation somewhat, among the options DOE has been exploring are sending the waste to other DOE facilities, to Federal non-DOE facilities, or to privately owned facilities. Each option is likely to encounter resistance from States and citizens. The policy implications of the privatization option, which DOE appears to be pursuing (147), require careful scrutiny. Putting defense TRU waste in the care of a private contractor

[97] NRDC v. EPA, 824 F. 2d 1258 (1st Cir. 1987); 26 ERC 1233, July 17, 1987 as amended Sept. 24, 1987; "Court Remands Nuclear Waste Site Rules, Cites Conflict with Drinking Water Law" Current Developments, Sept. 24, 1987, p. 848.

at privately owned facilities is a major break with past U.S. Government practice.

If further significant delays occur in the opening of a TRU waste repository, which could very well be the case,[98] retrievable stored TRU waste may have to be treated so that it can be safely stored on-site for longer periods than is now possible, given the present condition of the waste. Some of the six new TRU waste treatment facilities planned for 1992-99 could provide needed treatment capability. Planning for extended storage and enhanced treatment could also be compatible with the possible need to change the waste form to prevent gas generation in packages placed in the repository. The level of treatment desirable requires careful study; final recommendations of the Engineered Alternatives Task Force (EATF) for the WFP project are expected in 1991 and should provide valuable information.

Remediation of Buried Waste

The volume of buried TRU waste at Weapons Complex sites well exceeds that of retrievable stored TRU waste. Yet plans for remediating buried waste at Idaho, Hanford, and other sites are not very developed. Considerable attention is focused on one technology-in situ vitrification-which, although promising, may be of limited utility because of economic and other factors. Several alternative strategies need to be examined, with input from the public. If, in fact, the costs and occupational radiation exposures are considerably lower when waste is remediated on-site without exhumation, local communities will have to be convinced that the waste will not contaminate local water supplies or otherwise threaten public health. Careful research and monitoring as well as a credible outreach program will be necessary to provide such assurance.

The Waste Isolation Pilot Plant

In accordance with DOE planning and congressional intent, WIPP has remained a central element in DOE strategy for managing TRU defense waste. The WIPP geological salt bed facility has been constructed at a cost of about $700-800 million to serve as a research and development facility for TRU waste disposal. After a 5-year experimental phase, WIPP could become the final resting ground for retrievable stored and yet-to-be generated TRU defense waste. Secretary of Energy James D. Watkins developed a detailed decision plan, which was revised frequently, to help him decide whether to go ahead with WIPP; in June 1990, he made a positive decision on WIPP's readiness to proceed with a limited number of experiments. At present, the consensus of the various DOE technical oversight bodies supports preparation for limited emplacements of TRU waste in WIPP, in an attempt to resolve uncertainties prior to deciding whether to proceed with full operations.

WIPP currently represents the closest the United States has come to placing radioactive waste in a deep geologic repository, the option currently favored by DOE, EPA, and the Congress for disposal of both TRU and HLW. Although placement of the frost waste package in WIPP will be for experimental purposes only, and although the package so placed must be retrievable (in contrast to plans for operational disposal), such placement, if it occurs, will have symbolic importance. It could signify that after all these years the United States is finally doing something about TRU radioactive waste disposal. A degree of confidence could be restored in the ability of U.S. science and technology to eventually solve this tough radioactive waste disposal problem.

However, at this writing WIPP is still not a certainty. Matters that may still need attention prior to the start of the experimental phase include: DOE's operational readiness for radiation protection, monitoring, and other technical matters; resolution of the differences between DOE and the State of New Mexico concerning funds for highway improvements related to the transport of waste to WIPP.[99]

Congressional debate and legislation remain vehicles for those who either oppose WIPP entirely or wish to place certain conditions on its operations. For example, in 1991 the New Mexico congressional delegation introduced legislation to cancel the administrative withdrawal of land from the DOI to DOE.[100]

Two outstanding issues that pertain to WIPP's long-term performance as a repository are the adequacy of the present waste form and the nature of

[98] Under one scenario presented at a May 24, 1990, DOE Working Session on the WIPP Decision Plan and Rocky Flats Plant Alternative Storage Options, WIPP's startup is delayed until the year 2003 or 2004 due to the need to build and operate an alternative treatment facility for TRU waste.

[99] See also R.H. Neill and L. Chaturvedi, "Status of WIPP Project," paper presented at Waste Management '91, Tucson, AZ, February 1991.

[100] K. Schneider, "Plan on Starting Nuclear Waste Clears Big Hurdle," *The New York Times*, Jan. 23, 1991.

the final waste disposal standards for WIPP. At the April 26, 1990 WIPP hearings, there appeared to be a consensus among a wide spectrum of technical oversight individuals that the present TRU waste form could well prove unsatisfactory for two reasons: gas generation within the waste packages could result in situations that are too uncertain to predict with sufficient confidence; and EPA disposal standards for TRU waste might not be achievable, particularly under human intrusion scenarios. Disagreement centered on what to do about this situation. On the one hand, DOE is studying alternative waste forms and believes that the experiments will provide useful information. On the other hand, some believe that the experiments are not likely to shed further light on the situation, whereas improving the waste form will be valuable whether or not WIPP becomes operational. There was no discussion of how the waste form might be altered or at what cost. A study of possible options to the present TRU waste form is underway. It should provide a basis for evaluating options given the limitations of existing retrievable stored TRU waste, as well as uncertainties concerning the geologic repository.

A second broad issue concerns the disposal standards themselves. The disposal standards are currently being reworked. The Advisory Committee on Nuclear Waste of the NRC believes the standards are too strict. However, EEG has pointed out that EPA in 1982 relaxed the standard for permissible release of Transuranics from a repository, compared with high-level waste, by a factor of 3, after WIPP officials expressed concerns about meeting the previous limit.[101] As a result, because a TRU repository need comply with lower standards than a high-level waste repository, EEG opposes any further relaxation of the standard.

Disposal standards are an important consideration for those concerned about health and safety. Some have argued that no experiments should be allowed in WIPP until DOE demonstrates compliance with long-term disposal standards. The NRC holds that construction of a high-level waste repository in Yucca Mountain, NV, cannot begin until compliance with disposal standards is demonstrated. However, key decisionmaking authority for WIPP rests with DOE, not NRC. Also, DOE's position is that the experiments will be retrievable--it is not yet disposing of waste. DOE does not expect to be able to comment on WIPP's ability to meet disposal standards until completion of the performance assessment in 1994 or 1995.[102]

Finally, demonstrating that a geologic repository can safely contain waste for ten thousand years or more is a daunting task. When the WIPP facility is operational, waste in a TRU repository, as currently envisioned, will be irretrievable. Future generations might not consider these acceptable conditions. There are no easy solutions, but all options should be considered with as much public involvement as possible if WIPP is to receive full support.

Waste Minimization

Minimization of TRU waste is an area that might yield dividends in terms of easing the burden of cleanup and waste management. One promising area identified by DOE is in plutonium processing and manufacturing operations (53). DOE indicated in April 1990 that approximately $26 million (annually) is budgeted for research and development related to waste minimization[103] (85). It is not clear how much of this will be devoted to plutonium operations.

If waste minimization is defined as reducing the generation of new waste, then very little is being done in the area of TRU waste minimization. As DOE has indicated, "high-level and Transuranic wastes have not yet been given sufficient attention and emphasis in waste minimization planning' (86). Emphasis has been on reclassifying a portion of existing TRU waste as LLW and segregating hazardous from TRU materials. These are conceptually different from waste minimization and could *increase the* amount of waste of all kinds to be disposed of. All indications are that TRU waste minimization is just beginning to be considered at DOE and has a long way to go before benefits are obtained. The only substantive TRU waste minimi-

[101] J.K Channell, Environmental Evaluation Group, views on 'Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Tranuranic Radioactive Wastes (40 CFR 191),' presented to U.S. Nuclear Regulatory Commission, Advisory Committee on Nuclear Wastes, Mar. 23, 1990, pp. 7-8.

[102] Although OTA has not performed any in-depth study of congressional intent with regard to WIPP, the authorizing legislation would seem to indicate that it was meant to serve as a research and development facility although the January 1981 DOE Record of Decision on WIPP states that it is intended for disposal of waste. DOE's 1979 Draft Environmental Impact Statement envisioned the facility as having several functions, including serving as a full-scale repository for TRU waste as a step toward gaining experience for a high-level waste repository.

[103] Subsequently, this figure was increased to $44 million. Source: J. Marchetti, remarks at Waste Management '92, Tucson, AZ, February 1991.