MANAGING TRANSURANIC WASTE AT THE DOE NUCLEAR WEAPONS COMPLEX

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ABSTRACT

The safe storage, treatment and disposal of transuranic waste generated at the DOE nuclear weapons complex is an ongoing challenge, involving difficult technical, economic, regulatory and public policy choices. This paper provides a broad overview of aspects of DOE's defense transuranic waste management program and highlights several issues of continuing concern. The analysis was performed in conjunction with a larger assessment by the Office of Technology Assessment of the United States Congress of environmental restoration and waste management at the DOE weapons complex.*

OVERVIEW

It is 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. Whereas 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 revelation 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. Transuranic 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 transuranic materials.

Until 1970, TRU waste was handled in a manner similar to low- level waste: it was dumped into trenches or pits and covered over or buried; such waste is referred to as buried waste. Pre- 1970 practices have resulted in great uncertainty in the estimates and location of buried transuranic 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 retrievably stored waste. In general, the Department of Energy (DOE) views retrievably stored

* Any views or conclusions in this paper are those of the author, and are not necessarily those of the Office of Technology Assessment or Washington University.

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.

DOE's policy is that stored or 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 and built at a cost of $800 million 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 transuranic waste. 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; however, obstacles to initiating the experiments still remain. The earliest conceivable 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, both retrievably stored and buried TRU waste are distributed over six sites: the Idaho National Engineering Laboratory (INEL) has 61 percent of the retrievably 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 retrievably 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 projects a large increase in radioactivity associated with total stored TRU waste by the year 2013, growing to 3.5 times the 1988 value (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 transuranic waste as low-level waste. 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 transuranic waste and low-level waste also need evaluation.

BURIED TRANSURANIC WASTE

Characterization of and strategies for handling buried TRU waste or remediating TRU-contaminated soil are in the very early stages; knowledge of buried waste sites and soil contamination is far from complete. One example is the buried TRU Waste at Idaho National Engineering Laboratory (INEL). 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 requiring consideration are better definition 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 (RCRA) (3), involving EPA Region X, the Department of Energy (DOE), and the U.S. Geological Survey (USGS). An interagency agreement based on the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (4) is under preparation to address remediation of non-operating disposal sites. 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 low-level waste sites. However, EPA disposal requirements align TRU waste with high-level waste--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 which waste in which 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 RETRIEVABLY 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 Waste Isolation Pilot Plant (WIPP). The waste in these drums is soluble, respirable, and not generally fixed 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 1992-1999 for processing, treating, and certifying retrievably 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 will 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 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 (WIPP)

As of the summer of 1990, the experimental phase at WIPP still had not begun, and a series of obstacles remained to be overcome. Among those was the passage of legislation by the Congress to withdraw land from the public domain for WIPP use. 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 the EPA's disposal and no-migration standards for mixed transuranic 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, although the Department had stated that it would have preferred 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) calls for more contingency planning on DOE's part for waste storage; it also suggests 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. 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. Currently available information on gas generation rates have been used by some to show 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. 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 as significant changes in DOE waste management plans and facilities, would cause commensurate delays, and could increase worker radiation exposures.

There is no unanimity 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, experiments planned for the initial phase of the WIPP test program did not appear to include certain alternative waste forms that would generate less gas than the current preferred form. WIPP was authorized by Congress as a research and development facility to demonstrate safe disposal of transuranic waste; yet, as it is now constituted, the program proposed by DOE does not appear to have convinced its opponents that all important concerns have or will be addressed.

STANDARDS, REGULATIONS, AND OVERSIGHT

EPA disposal standards represent the primary line of defense for public health and safety against radioactivity from transuranic 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 in November, 1990. With regard to mixed TRU waste stored at DOE facilities, there is a dilemma in that 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, and in light of the limited capacity available nationwide to treat mixed TRU waste, EPA issued on June 1, 1990, a two-year variance to provide sufficient time for building the capacity required to treat the mixed waste generated and stored at facilities such as those in the DOE Weapons Complex. As a consequence, 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 singles out three specific areas for TRU (retrievably stored or newly generated) waste management: 1) better waste treatment to meet

WIPP certification requirements; 2) disposal options for waste not certifiable for WIPP; and 3) better characterization of RCRA components in waste for certification. There is also material in the plan applicable to buried waste. The plan lists a number of technologies that might prove useful for the remediation effort but does not evaluate or prioritize 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 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 transuranic 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 to acceptable levels after disposal. One reason given for continued funding of the Fast Flux Test Facility at Hanford is for just this purpose. However, transmutation is still in the research and development stage; it is not a part of recent DOE five year waste management operations plans, nor is it likely to prove useful for TRU waste management over the next ten years. These are also significant obstacles to transmutation becoming a major factor in TRU waste management over the long-term.

REFERENCES AND NOTES

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.
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 by 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)).
4. Pub. L. No. 96-510, 94 Stat. 2767 (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. 9601-11050 (West 1983 and Supp. 1990).
5. FRED DOWSETT, Colorado Department of Health, personal communication, January 4, 1991.
6. This position is inconsistent with the parallel case of the Yucca Mountain, NV, high-level waste 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.