MANAGING HIGH-LEVEL WASTE AT THE DOE NUCLEAR WEAPONS COMPLEX

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ABSTRACT

The safe storage, treatment and disposal of high-level radioactive waste generated at the DOE 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 high-level 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

The first high-level defense waste was created as a by-product of the production of plutonium in a natural uranium-graphite reactor at Hanford and the subsequent remote "reprocessing" of irradiated uranium fuel elements to recover plutonium. The by-product was a highly radioactive, acidic, aqueous solution containing a variety of fission products with a wide range of half-lives, as well as residual uranium and some residual radionuclides with larger atomic numbers than uranium--the transuranics. It was recognized that this liquid high-level waste (HLW) required careful handling, as well as isolation from people and the environment for many years. Huge, underground, single-shell carbon steel tanks, eventually 149 in number, were built to store neutralized liquid HLW at Hanford. An early practice of discharging some of the liquid from the high-level waste tanks into "cribs" and then into the soil was subsequently discontinued. Some tanks began to leak, and new tanks of double-shell design were added.

High-level defense waste is generated by reprocessing spent fuel and irradiated uranium targets from Department of Energy (DOE) weapons material production reactors. The waste, a mixture of fission products, uranium and transuranic radionuclides, is generally distinguished from other radioactive waste types by its intense radioactivity coupled with the longevity of its hazard. Most liquid high-level waste has been neutralized, forming mixtures of liquid, sludge and salt cake, and is currently stored on-site in steel tanks, some of which have leaked and represent a potential threat to groundwater. Storage of waste in less expensive carbon steel, rather than stainless steel, tanks after neutralization of acidic high-level waste requires complicated waste handling and treatment. Concern also exists about the possibility of explosion in the waste tanks, accompanied by the release of radioactivity.

Four DOE sites have high-level waste: the Hanford Plant, the Savannah River Site, the Idaho National Engineering Laboratory (INEL), and West Valley, NY; the last, a nonweapons site, reprocessed some fuel commercially from 1966 to 1972. The prime contractors for the management of HLW at all four sites are subsidiaries of Westinghouse. The two sites that have more than 90 percent of the high-level waste by both volume and radioactivity--Savannah River and Hanford--are planning to begin operations to immobilize HLW in 1992 and 1999, respectively although slippage of these schedules would not be unusual. The Savannah River vitrification facility was built at a cost of about one billion dollars. The Hanford facility is not yet designed but will probably be very similar to Savannah River. The West Valley site is also scheduled to begin vitrifying waste in 1996; the cost of all West Valley operations, including decontamination and modification of existing facilities to accommodate vitrification as well as new construction needed for the vitrification plant, will be on the order of one billion dollars. Canisters of vitrified waste ("glass logs") are to be stored on-site, pending disposal in a deep geologic repository that is not expected to begin operation until the second decade of the 21st century. In contrast to the other three sites, for 25 years INEL has been converting liquid high-level waste from the reprocessing of highly enriched uranium-235 spent fuel from naval and other reactors to a powdery solid calcine and storing it in stainless steel bins; DOE has not made a final decision about the waste form for immobilization and disposal of INEL high-level waste.

At West Valley, DOE is reducing the volume of high-level tank waste to be vitrified by separating a portion of the waste that has relatively less radioactivity, mixing it with cement, and temporarily storing it in drums above ground, pending a disposal decision through the Environmental Impact Statement (EIS) process. An analogous separation

* 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.

is planned for Savannah River and Hanford because it will greatly reduce the amount of waste to be vitrified and should substantially reduce disposal costs if the portion immobilized in grout or concrete can be disposed of on-site at or near the surface. At West Valley, DOE sought and obtained Nuclear Regulatory Commission (NRC) approval to perform such a separation; NRC appears to have oversight authority under the West Valley Demonstration Act of 1980. However, there appears to be no such NRC authority at the weapons sites. Concerns have been raised by interested members of the public about the legality and safety of such waste separation; the grouted waste at West Valley is reported to be "Class C low-level waste" containing technetium-99, a long-lived (210,000-year half- life) beta emitter. Nevertheless, DOE is moving ahead, indicating that it has all necessary permits from the State of South Carolina to begin "saltstone" operations at Savannah River; by July, 1990, those operations were underway but not using waste from the main high-level tank farm.

Uncertainty exists about the composition of high-level waste at DOE weapons sites. The uncertainty arises because of the variety of processes that have been used, the past mixing of wastes, and the heterogeneity of tank components after neutralization. Sampling is very difficult because of tank design, the high radioactivity levels, and concern about the possibility of tank explosions. Knowledge of waste composition is important in designing waste treatments and it is needed for proper glass- waste formulation for the vitrification process.

Historically, the regulatory framework for high-level waste at weapons sites has been the province of DOE and its predecessor agencies under the Atomic Energy Act (1). However, EPA has recently become a major factor in regulating the sites through its jurisdiction over hazardous waste and application of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) to these sites. State agencies have also gotten involved through mechanisms such as the Hanford tri-party agreement. Regulations can be numerous and complex, as in the case of possible regulations governing cleanup of Hanford single- shell tanks.

Regulation of hazardous materials is the mechanism that has served to break somewhat the cycle of self-regulation by DOE. However, hazardous waste violations may not be the most significant ones, especially in the area of high-level waste. For example, the Plutonium and Uranium Extraction (PUREX) plant at Hanford was shut down in part due to hazardous "listed wastes" violations. Yet in considering restarting this aging plant that was shut down with highly radioactive material distributed throughout the system, the main threat may not have been from hazardous materials but from radioactive ones. Sampling of HLW tanks is another area in which hazardous waste regulations may ignore radiological threats.

The basic thrust of the HLW management program of DOE is to move from the present less secure, less stable, less controlled condition to a more stable one by immobilizing the tank waste. High-level waste vitrification, if successful, should reduce the threat of groundwater contamination and tank explosions posed by liquid high-level waste stored in tanks. An objective of vitrification is to produce a waste form that will immobilize waste safely for hundreds or thousands of years; however, the process chosen involving borosilicate glass, has yet to operate on a large scale in the United States (2) and long-term performance of the vitrified waste form in various settings is difficult to predict and hard to verify. If vitrification works as planned, the glass logs produced represent a potentially stable form for long-term storage on-site or in a monitored retrievable facility if the deep geologic repository should be delayed. DOE and most experts working within the DOE framework believe that at present, vitrification using borosilicate glass is the best available technology for geologic disposal.

THE TRANSITION TO MORE STABLE WASTE FORM

A significant transition is beginning to take place from the less secure and more threatening storage of high-level waste in tanks to the more promising secure storage of immobilized high-level waste (HLW) in solid, glasslike form. Bringing about this transition is a major and costly undertaking, and a successful outcome is far from being achieved. However, if it can be accomplished with minimal occupational risk to workers, it should greatly reduce if not remove the current, ever-present threat and concern regarding tank leaks and explosions. The nominal design lifetime of vitrified waste using borosilicate glass is such that even if a geologic repository were delayed significantly, the glass logs could be stored safely on-site at Savannah River and Hanford for hundreds of years, as long as the necessary institutional controls remain in place. Calcine, even without immobilization in glass or ceramic, also appears able to be safely stored for hundreds of years at the Idaho National Engineering Laboratory (INEL).

The legacy of past practices in which high-level waste was discharged into cribs or stored in 149 single-shell tanks at Hanford must still be dealt with; the Department of Energy (DOE) has not yet decided how to accomplish the necessary decontamination and safe disposal.

MONITORING THE WASTE FORMS

Because of the importance and the cost of vitrification to improve the safety and stability of HLW storage and disposal, it is essential to carefully monitor and regulate the integrity and hazard potential of the waste forms, including both vitrified and concrete products. Continuing studies and monitoring are required to resolve opposing claims that may arise concerning safety and health risks during storage, along with a continued strong research program on waste stability (3), container integrity, and radionuclide transfer through the environment.

FORM OF HIGH-LEVEL WASTE AT THE IDAHO NATIONAL ENGINEERING LABORATORY

The decision to produce a dry, calcined waste form for the storage of high-level waste at INEL has provided considerable experience with an alternative to the approach used at Hanford and Savannah River. At present, work is focusing on glass ceramic as a promising medium for immobilization of the calcine in order to reduce disposal costs relative to the use of borosilicate glass. Cost, although important, is but one factor to be considered. Environmental integrity in response to evolving, possibly tightened environmental standards for radioactivity is another.

Calcining appears to be a proven, relatively low-cost means of solidifying liquid waste and a viable medium-term (about 500 years) alternative to vitrification. More research on the calcined waste form and on bin hardening of calcine for disposal could supply data for use if some future treatment, interim storage and/or disposal alternatives were considered.

HIGH-LEVEL WASTE REPOSITORY

The U.S. approach to high-level waste disposal is to license and use a geologic repository to contain potentially harmful radionuclides for the tens or hundreds of thousands of years that may be necessary. The Swedish approach places more reliance on engineered barriers, including a thick container wall to provide the necessary isolation; other European countries are also focusing on engineered barriers. By contrast, in the United States, current policy places reliance on the geologic repository itself.

The U.S. high-level defense waste glass logs are to be formed in thin-walled canisters that meet Nuclear Regulatory Commission (NRC) repository criteria; the canisters will then be put in containers before repository emplacement. It may be useful to consider placing more reliance on engineered barriers for isolating the waste, for example, by increasing either canister thickness or container thickness and backfill, or by some combination of these modifications for the geologic repository setting.

STANDARDS FOR HIGH-LEVEL WASTE DISPOSAL

Standards for disposal of high-level waste have been remanded by the courts but are expected to be reissued for comment by the Environmental Protection Agency (EPA) (4). These standards have important implications for defense high-level waste. The long term trend has been to issue progressively more stringent standards for nuclear waste disposal as new information becomes available about health risks from radiation exposure. This trend may continue but the process is very slow and thus has hindered planning for ultimate safe disposal.

TIME FRAME FOR IMMOBILIZATION

Decisions about the urgency and rapidity with which liquid high- level tank waste should be immobilized are difficult to make because of the lack of good information on the contents of some tanks or on the movement of radioactive and hazardous materials that have leaked from tanks. In the absence of such information, and given continuing concern about the possibility of waste tank explosions, it may be prudent to move forward with vitrification projects as quickly as feasible and to make sure that technical environmental, and policy questions or concerns are addressed promptly and effectively as well. Trade-offs between moving ahead with dispatch and moving ahead too precipitously require careful consideration. Among the current concerns are the possibility of explosion when disturbing or heating tanks or tank contents, including those containing ferrocyanide. Also, occupational radiation doses should be carefully controlled and monitored.

AIRBORNE RELEASES

Airborne release of both radioactive and hazardous materials is a significant potential health threat from DOE weapons sites. the movement of contaminants in the air is direct and rapid compared with movement via groundwater. Reactors, reprocessing plants, and HLW treatment operations all involve some routine air emissions; in addition, there is the possibility of accidental release. Although air releases have been greatly reduced from the early days of the weapons program, attention to air emissions is continually important, both in setting standards and in monitoring waste management activity.

FUTURE OF THE PUREX PLANT AT HANFORD

The Plutonium and Uranium Extraction (PUREX) fuel reprocessing plant has been of concern because of its age, the large amounts of hazardous and radioactive wastes it produces, past atmospheric releases, and continued release of liquid effluents to the soil. DOE had planned to restart PUREX to reprocess backlogs of spent defense fuel over a five-year period and then to permanently close the facility. Of concern is the 2,100 metric tons of metallic spent fuel from the Hanford N reactor awaiting reprocessing and currently being held in water basins at K plant, near the Columbia River. DOE needs to prevent any radionuclide release from failed fuel elements since these basins have leaked in the past.

In October, 1990, DOE announced that it would not restart PUREX for at least 2 years but would prepare an Environmental Impact Statement (EIS) to evaluate a variety of treatment and disposal methods for stored N reactor fuel (5). Some have interpreted this announcement as indicating that PUREX will never again operate (6). If and when it is prepared, the planned EIS should be structured to allow full consideration with public input of the impact of alternatives to restart, including the consequences of continued storage of fuel elements in the K basins.

LEARNING FROM INTERNATIONAL EXPERIENCE

Because of the U.S. decision in the 1970s not to encourage reprocessing of commercial nuclear fuels, other nations have moved ahead in acquiring expertise in reprocessing that could prove useful to DOE's fledgling efforts at waste minimization. Learning from these international sources could be part of a necessary upgrading of DOE waste minimization activity, particularly in planning for any new reprocessing capability in connection with modernization of the weapons complex.

FUNDAMENTAL ISSUES

Some fundamental questions or issues need to be addressed in a programmatic Environmental Impact Statement (EIS) or other appropriate forum concerning the high-level waste management program at DOE. First, are the risks to worker safety and health warranted to convert high-level waste from a less stable, controlled, or secure liquid or sludge form to a more stable, immobilized solid form, given the potential reduced risks and reduced potential threat to the public from the solid form? Second, if most, or perhaps all, of the free liquid will be removed from Hanford single-shell tanks by the mid 1990s, is some in situ treatment available for tank sludge and for the tanks themselves that might preclude costly and possibly risky removal operations? If so, would leaving treated wastes on-site prove acceptable to people nearby? Third, is having a geologic repository as the sole disposal option for high-level waste a viable strategy? Vitrified waste canisters could be designed to last for hundreds of years if stored on-site or in a monitored retrievable facility. Should more attention be given to the possibility that vitrified HLW will remain in storage at each site and will require long term monitoring and controls?

REFERENCES AND NOTES

1. 42 U.S.C., 2011-2296 (1982 and Supp. IV 1986).

2. There is however, considerable experience with commercial HLW vitrification in Europe, especially France, using a process somewhat similar to that built at or planned for those DOE facilities.

3. Factors concerning waste stability over the long term that need investigation include: leaching, embrittlement, and corrosion.

4. "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes", 40 C.F.R. 191 (1989).

5. N. K. GERANIOS, "Plutonium Processing Plant Won't Reopen, Energy Secretary Says", Associated Press News Release, October 17, 1990.

6. C. HOLDEN, ed., "Bailing Out of the Bomb Business", Science, November 9, 1990, p. 753.