VOLUME 7, NUMBER 3 MAY 1999

Science for Democratic Action

AN IEER PUBLICATION

# Short- and Medium-Term Management of Highly Radioactive Wastes in the United States

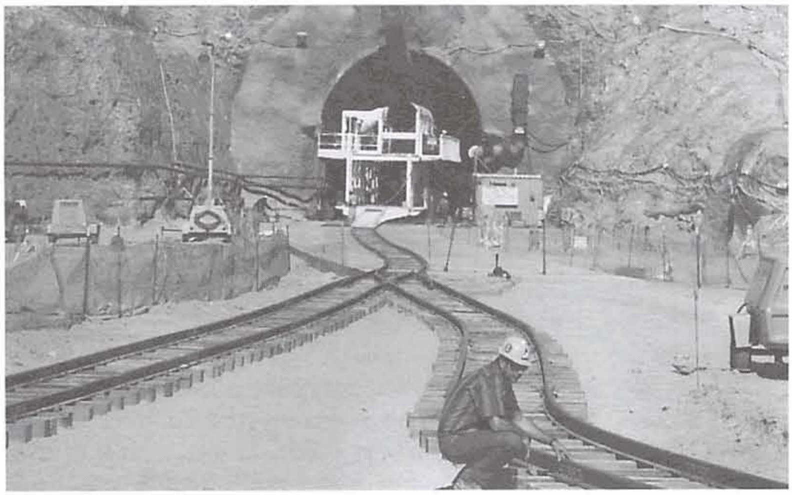
ARJUN MAKHIJANI[1]

The United States Department of Energy (DOE) is simultaneously pursuing two inappropriate geologic repository projects for disposal of highly radioactive waste:

- The Waste Isolation Pilot Plant (WIPP) in New Mexico, which is supposed to "solve" the problem of wastes containing high concentrations of transuranic radionuclides, such as plutonium, mainly arising from the US nuclear weapons production program.[2]
- The Yucca Mountain repository in Nevada, which is being explored for its suitability for disposing of irradiated nuclear reactor fuel (also called spent fuel) and the high-level radioactive waste that results from the reprocessing of irradiated fuel. These two categories of waste, which often go under the single rubric of "high-level waste," together contain over 99 percent of all the radioactivity in all nuclear waste.

For a host of reasons, that IEER and others have addressed elsewhere, both of these repository projects are unsuitable, driven not by environmental protection but by politics and artificially-created legal deadlines.[3] They are subverting environmental goals instead of promoting them. For instance, the most environmentally threatening transuranic (TRU) waste is that which was dumped in shallow landfills prior to 1970 at various DOE sites. These leaking waste dumps have contaminated large volumes of soil and are threatening important water resources. But because of the focus on WIPP, the buried waste problem has festered for lack of funds, research, and sufficient interest.[4]

SEE SHORT TERM PAGE 16, ENDNOTES, PAGE 19



*View of the north portal entrance to the Exploratory Studies Facility at Yucca Mountain, the proposed site for a repository for highly radioactive waste, located, about 100 miles northwest of Las Vegas on the edge of the Nevada Test Site.*

# Considering the Alternatives

**Creating a framework for sound long-term management of highly radioactive wastes in the United States**

ARJUN MAKHIJANI

The management of long-lived radioactive wastes is one of the most vexing and difficult challenges created by modern technology. Some radionuclides will persist for millions of years. Plutonium-239, present in substantial quantities, can be used to make nuclear weapons, making the reversal of any disposal attractive for future proliferators. Solutions to reduce the longevity of the wastes by transmutation, possible in theory, create intolerable proliferation risks and leave residual contamination and waste that would still require long-term management. Also see page 16 for a description of rejected high level waste management methods.

In other words, there are no ideal options for managing highly radioactive waste. The menu is a poor one and any "solution" will be from among options that each have some drawbacks. That is one reason why phasing out nuclear power and stopping nuclear weapons production, both of which should be done for other reasons as well, are important complements to the search for the

SEE CONSIDERING ON PAGE 2, ENDNOTES, PAGE 20

INSIDE

## CONSIDERING

FROM PAGE 1

least environmentally destructive waste management approaches. Difficult as it may be to accept, it is highly unlikely that there will be any future technological "silver bullet" that addresses all of the important technical, environmental and proliferation issues simultaneously, even if cost is left out of the picture. Above-ground storage for the indefinite future is also not an option (see article on short- and medium-term steps, page 1). Inaction is a recipe for even more problems.

Further, in the real world, the resources devoted to any one problem are necessarily limited. So far, massive amounts of money have been spent on unsuitable, politically-driven projects, notably the Yucca Mountain project in Nevada and the Waste Isolation Pilot Plant in New Mexico. As the recent placement of wastes in WIPP without a state hazardous waste permit shows, spending a lot of money on a hole in the ground creates political pressure to open such repositories, no matter how environmentally unwise that might be.

The placement of waste in WIPP proves nothing more than that the economic and political forces behind such placement are, at least for the moment, more powerful than those opposed to the opening of the repository. It does not change the fact of the pressurized brine reservoirs in the area, or of the resources located there that make the possibility of human intrusion a severe problem at the site. Ignoring these problems is an expensive and dangerous continuation of the nuclear establishment's "out of sight out of mind" approach to nuclear waste management. This is a poor way to approach the scientific and technological challenge of minimizing the potential and actual damage from the waste that has already been generated.

A sound waste management program needs to be structured so that sufficient resources can be expended on several options, which will enable reasonable comparisons to be made. Of course, sound comparisons will require sound science, which makes the institutional framework for the long-term research at least as important as the technical issues. (See article on institutional reform, page 21.)

This article outlines three broad approaches that may in some measure meet the goal of isolating waste from the human environment for the necessary period (hundreds of thousands or millions of years):

1. geologic disposal — disposal in a land-based deep repository within the Earth's crust
2. sub-seabed disposal — disposal in the ion-absorbing soft clay sediments beneath the sea floor
3. disposal under the Earth's crust.

### Geologic Disposal

Geologic disposal has been the most studied approach to long-term nuclear waste storage. The basic concept is to dispose of the waste in a deep repository in containers surrounded by other engineered barriers such as special backfill materials. The only location being investigated in the United States for spent fuel and military high-level waste is the Yucca Mountain Site in Nevada, which consists of volcanic tuff. A five-mile long tunnel has been

SEE **CONSIDERING** ON PAGE 8
ENDNOTES, PAGE 20

## Science for Democratic Action

*Science for Democratic Action* is published four times a year by the Institute for Energy and Environmental Research:

6935 Laurel Avenue, Suite 204
Takoma Park, MD 20912, USA
Phone: (301) 270-5500
FAX: (301) 270-3029
E-mail: ieer@ieer.org
Web address: www.ieer.org

**The Institute for Energy and Environmental Research (IEER)** provides the public and policy-makers with thoughtful, clear, and sound scientific and technical studies on a wide range of issues. IEER's aim is to bring scientific excellence to public policy issues to promote the democratization of science and a healthier environment.

### IEER Staff

**President:** Arjun Makhijani, Ph.D.
**Librarian:** Lois Chalmers
**Bookkeeper:** Diana Kohn
**Project Scientist:** Annie Makhijani
**Outreach Coordinator:** Lisa Ledwidge
**Global Outreach Coordinator:** Anita Seth
**Administrative Assistant:** Betsy Thurlow-Shields
**Project Scientist:** Hisham Zerriffi

### Thank You to Our Supporters

We gratefully acknowledge our funders whose generous support has made possible our project to provide technical assistance to grassroots groups working on nuclear weapons-related issues, and our global outreach project.

W. Alton Jones Foundation • John D. and Catherine T. MacArthur Foundation • Public Welfare Foundation • C.S. Fund • HKH Foundation • John Merck Fund • Ploughshares Fund • Unitarian Universalist Veatch Program at Shelter Rock • Town Creek Foundation • Beldon II Fund • Turner Foundation • New Land Foundation

Thanks also to the SDA readers who have become donors to IEER. Your support is deeply appreciated.

### Credits for This Issue

*Production:* Cutting Edge Graphics

*Science for Democratic Action* **is free to all readers.**

Editors: Lisa Ledwidge and Anita Seth

# "Rush to Rent"[1]: DOE's Leasing of Contaminated Facilities is Putting Workers at Risk

LISA LEDWIDGE[2]

"Reindustrialization" is a new program of the Department of Energy (DOE) in which space and equipment at US nuclear weapons sites are leased to private companies, most of whose work has nothing to do with nuclear materials or radioactivity, to help reduce the cost of and accelerate cleanup. Reindustrialization, a form of "privatization" of DOE facilities, is currently under way at the Oak Ridge nuclear weapons site near Knoxville, Tennessee.

Some of the space that DOE is leasing is contaminated with residual radioactivity. The workers who will be using these facilities are being put at some risk of exposure, but without their informed consent or the protections that are normally given to radiation workers.

The Oak Ridge reindustrialization plan has been met with criticism from the public, labor unions and other government agencies, including the Oversight Office of Environment, Safety and Health (ESH) of the DOE itself, which noted that:

> The reindustrialization program at ETTP [East Tennessee Technology Park, at Oak Ridge], including the leasing of buildings, space, and equipment, has been implemented without ensuring that health and safety requirements, accountability for performance, DOE roles and responsibilities, and liabilities are clearly defined.[3]

While reindustrialization may be a viable concept in principle under some circumstances, the DOE program at Oak Ridge is poor in substance and process. As has become common with many of its projects, the DOE is rushing into the program at Oak Ridge without adequate preparation. The reindustrialization program at Oak Ridge has three fundamental problems:

- The DOE is leasing contaminated buildings.
- The contaminated buildings pose risks to the health and safety of lessee workers.
- The DOE has failed to establish oversight and a regulatory framework for protecting the health and safety of lessee workers.

The problems associated with the protection of private-sector workers in Oak Ridge's reindustrialization program pose major safety and health questions. The DOE hopes to reduce clean-up costs and provide cheap space and other facilities to private companies. Instead of cleaning up the mess it made during the Cold War and protecting the public from residual hazards, the DOE is bringing the public, in the form of workers, within the perimeters of its contaminated sites and exposing them needlessly to those hazards. By proceeding in this way, the DOE is putting yet another generation of workers at risk.

### Background

The leasing or transferring of DOE property formerly used in nuclear weapons production to the private sector began in the early 1990s. Examples include the cleanup, conversion and transfer of the Pinellas Plant in Florida to the county of Pinellas and the cleanup, conversion and ongoing transfer of the Mound Plant in Ohio to the city of Miamisburg, both for use as industrial office parks.

The DOE began leasing facilities at Oak Ridge to private companies in 1996. The leased facilities are within the former K-25 site (now called ETTP, or the East Tennessee Technology Park). Some of the lessees contribute to the decontamination and decommissioning of the facilities in return for use of workspace, equipment and utilities. Currently, there are approximately 40 leases among 18 private companies which employ approximately 225 people.[4] DOE-Oak Ridge expects the net savings from current leases at the site to exceed $800 million in about 30 years.[5]

### Contaminated Buildings for Lease

Under the reindustrialization plan, DOE-Oak Ridge and its leasing agent, the Community Reuse Organization of East Tennessee, are leasing contaminated facilities to private companies. Most of the companies are industrial manufacturing firms; all employ workers from the general public. Some, though not all, of the leased facilities contain residual radioactive contamination. As noted by the DOE ESH Oversight Office:

> OR [DOE Oak Ridge Operations Office] has ... leased spaces within a building that have not been fully decontaminated and that still contains [sic] potential worker hazards, including radiological contamination, asbestos, and fissile materials.[6]

> The spaces...were cleaned by scraping, "chipping out," and painting sections of floors and lower portions of walls (below 8 feet) known to be contaminated.[7]

The spaces to which ESH Oversight refers are located in building K-1401, which contains residual radioactive contamination embedded in some of its concrete and steel structures.[8] The building's 35-foot

SEE **RUSH TO RENT** ON PAGE 4,
ENDNOTES ON PAGES 7-8

**RUSH TO RENT**
FROM PAGE 3

walls are decontaminated to only eight feet. The lease stipulates that the tenant must contact DOE officials to change a light bulb or do anything else above the eight-foot line since radioactive contamination could be present there. The lease restrictions also indicate that tenant is not allowed to chip the concrete floor or punch holes in the walls.[9] The basement of K-1401, which is locked and off-limits to lessee workers, contains several hazards including fixed and removable radiological contamination, loose asbestos, contaminated groundwater, and fissile materials.[10]

### Risks to Workers and the Public

Contamination in ETTP facilities has already led to exposure of workers to hazardous materials. It was recently reported that five current or former K-25/ ETTP workers were exposed to beryllium, a toxic substance, which can lead to chronic beryllium disease, an irreversible and debilitating respiratory illness resembling emphysema.[11] The physicians who reported the problem stated:

> We have recently become increasingly concerned that there is a potential for ongoing worker exposure to beryllium compounds at K-25/ ETTP. [I]t has been documented that several buildings...have contained and/or currently contain beryllium compounds. ...Past experience has shown that these compounds spread and migrate out of areas in which they were originally contained.[12]

Worker safety at Oak Ridge leased facilities was also criticized in a January 1999 report by a team of experts from the Occupational Safety and Health Administration (OSHA), the DOE, and labor unions.[13] Though the report did not evaluate radiological contamination in the leased facilities, it did identify several potential violations of standards — most of them deemed "serious" — for various hazards and issues, including electrical, machine safety, fire safety and respiratory protection (Appendix D). It revealed that some tenants had not been informed about all of the hazards present in the facilities (p.49). In addition, OSHA stated that some of the information it received about the condition and status of reindustrialized facilities was "out of date, inaccurate and/or incomplete" (p.47).

Despite criticisms about the safety of leased facilities, DOE-Oak Ridge has invited, in addition to lessee companies, other members of the general public into contaminated buildings. In June 1998, DOE and its contractors held an auction in building K-1401, a facility known to be contaminated, to sell decontaminated machinery from various buildings at the former K-25 site. More than 300 people attended, mostly buyers from machine shops from different areas of the eastern United States.[14]

The danger of leasing contaminated buildings is made more apparent by examining the clean-up process. In some areas, the DOE is covering up contamination by simply applying layer(s) of paint to contaminated surfaces. Its own regulations[15] require signs be posted to warn of the presence of residual contamination, but Oak Ridge has not done so in at least one case.[16]

Another example is the continuation of decontamination work in leased facilities among lessee workers. In building K-1401, DOE workers in radiation protection gear are "scabbling" (shaving or sanding off one or more layers of) radiologically contaminated concrete. This work is taking place in areas near lessee workers, who are not required to wear respiratory protection and are not individually monitored for radiation exposure.[17] Clearly, the lessee workers are not being adequately protected.

According to Charles Lewis of DOE's ESH Office of Oversight, Oak Ridge "could consider doing more as

SEE **RUSH TO RENT** ON PAGE 5.
ENDNOTES ON PAGES 7-8

### THE OAK RIDGE SITE

In the 1940s as part of the Manhattan Project, a massive facility for the enrichment of uranium was built at Oak Ridge, Tennessee, about 20 miles northwest of Knoxville. The 5,000-acre K-25 industrial complex, named for one of its buildings, the K-25 plant (at the time the largest building in the world), used a gaseous diffusion process to produce highly enriched uranium (HEU) for use in nuclear weapons, including the Hiroshima bomb.

The process resulted in the production of a number of radioactive and hazardous wastes, among them depleted uranium, PCBs, chlorine, ammonia, nitrates, zinc and arsenic. It also resulted in the release of fluorine gas and hexavalent chromium into the atmosphere. Enrichment facilities at the Oak Ridge site were closed down in late 1987 but some of these wastes, including several hundred thousand gallons of PCBs, dozens of miles of asbestos-lined pipes, and hundreds of tons of radioactive scrap, remain in the buildings on the site.

**Sources:**

Arjun Makhijani, Howard Hu and Katherine Yih, ed., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects*, (Cambridge, Massachusetts: MIT Press), 1995, p. 43.

The Foundation for Global Sustainability, Oak Ridge Education Project, *A Citizen's Guide to Oak Ridge*, Knoxville, Tennessee, May 1992, p. 20.

## RUSH TO RENT

FROM PAGE 4

far as radiological monitoring. They have elected not to monitor individual lessee workers, or lessee products going off site, from partially contaminated facilities, but the technical basis for these decisions have [sic] not been documented."[18]

The DOE's risk assessment of building K-1401 (done by Science Applications International Corporation) indicates that the leasing would result in routine exposures of workers to radiation that the workers would not have if they were working in commercial spaces. These exposures would result from alpha-emitting radionuclides like uranium and plutonium-239 (with doses from the former being predominant) as well as beta emitters and increased gamma radiation.[19] Even if one presumes that the DOE dose and risk calculations have been properly done (see below), exposing workers unnecessarily violates the principle of keeping exposures as low as reasonably achievable. This precept for worker and public health protection, known as the ALARA principle, has been a part of DOE and Nuclear Regulatory Commission regulation of nuclear facilities under the Atomic Energy Act for decades.

Further, DOE's cumulative doses and risks are not conservative. Some leases are as long as 40 years, but doses are added for only 10 years.[20] The 40-year cumulative dose would be about 450 millirem from inhalation alone, according to DOE calculations.[21] The DOE reports a variety of figures for risk from external radiation. For individual hot spots, the risks correspond to doses of several tens of millirem per year, corresponding to cancer risks of up to about 4 in 100,000. Yet in other documents the DOE reports a ten-year risk that is only one-tenth this amount.[22]

Moreover, the inhalation dose calculations are based on 1995 conditions, and do not appear to include the effect of clean-up activities being undertaken while the building is actually occupied. The combined effect of past clean-up with the additional contamination due to continuing clean-up activities does not appear to have been estimated. Finally, the exposures to non-radioactive materials must be added to these radiation risks.

### Lack of Oversight

The DOE has failed to establish clear responsibility for oversight of worker health and safety at Oak Ridge's leased sites. When asked January 1999 who is in charge of the safety of lessee workers, Dr. David Michaels, director of DOE's Office of Environment, Safety and Health, replied, "That is something we are trying to clarify right now."[23] Yet the DOE has been leasing contaminated buildings at Oak Ridge for about three years.

The US Nuclear Regulatory Commission (NRC) currently has no authority over the leased facilities; the NRC generally oversees safety of radiation work only at non-DOE nuclear enterprises, like nuclear power plants. DOE-Oak Ridge has taken the position that workers in leased space are subject to OSHA safety authority, not DOE requirements; but OSHA has not officially accepted an active oversight role.[24] DOE-Oak Ridge has set forth in the leases that lessees must comply with OSHA laws and regulations, and claims it has authority to punish tenant violators of health and safety regulations by terminating their lease.[25]

Because there is currently no external oversight for lessee worker safety at the leased facilities, the provisions and restrictions in the leases have become the central means for ensuring compliance with health and safety regulations. This is a highly questionable arrangement because it is not clear if or how Oak Ridge and its leasing agent, the Community Reuse Organization of East Tennessee (whose mission is to "move the Oak Ridge Complex's resources toward private management quickly and efficiently"[26]), would enforce OSHA compliance, especially considering the need of both entities to lease space to support cleanup and economic development. In this context, regulation of worker health and safety by DOE-Oak Ridge and/or CROET entails a clear conflict of interest.

There is also inconsistency in the process of determining whether DOE facilities are "clean enough" to be leased. At Mound, DOE facilities are being leased to private companies, and ultimately will be transferred to the city of Miamisburg, under the Hall Amendment to the National Defense Authorization Act of 1994. The Hall amendment stipulates that the DOE must consult and obtain, before entering into a lease, concurrence from the Environmental Protection Agency (in the case of Superfund sites, which includes Oak Ridge, Mound and many other DOE sites) that the property is "clean enough" to lease out or transfer. The Hall Amendment does not explicitly stipulate a level of radiation protection for lessee workers. But it implicitly leaves open the possibility of protecting workers as members of the general public and provides for greater public involvement and outside oversight of leasing activities compared to the current approach at Oak Ridge.[27]

At Oak Ridge, however, the DOE contends that coverage by the Atomic Energy Act, passed in 1954, excludes Oak Ridge leasing activities from Hall Amendment requirements. A 1998 memorandum from its General Counsel explains DOE's legal interpretation:

> [O]ur review indicates that section 161g. of the AEA provides authority to lease property that has been used, or that under the lease will be used, to carry out functions of the AEA. The Hall Amendment, in contrast, provides leasing authority relating to economic redevelopment of DOE facilities that are being closed or reconfigured.[28]

SEE **RUSH TO RENT** ON PAGE 6,
ENDNOTES ON PAGES 7-8

In other words, DOE is claiming that the Hall Amendment is applied only if there is an exclusive end-state of economic development, whereas the Atomic Energy Act is applied if there is an impact to a DOE program or mission.[29] However, the language of the Hall Amendment sets forth no distinctions related to the purpose of leasing. So in effect, the DOE is making an artificial distinction between what it calls "economic development" at Mound and "reindustrialization" at Oak Ridge.

Since DOE has not yet provided sufficient data to the EPA for it to make a determination on the safety of the leased facilities at Oak Ridge,[30] EPA maintains that it is not prudent to continue leasing property there to the private sector.[31] Community groups around Oak Ridge support this notion and have requested that, if DOE's non-compliance with the Hall Amendment continues, the EPA bring the issue to the attention of the Justice Department.[32] At the time this issue went to print, DOE and EPA had started a pilot project to help resolve their differences.[33]

### Lack of Protective Standard for Lessee Workers

Three years after the start of leasing at Oak Ridge, the DOE is still in the process of developing a policy for reindustrialization, including a radiation protection standard for workers in the leased facilities. Neither the workers nor their representatives have been invited to participate in this process.[34]

A key issue in the internal DOE debate is whether reindustrialization should be considered a "DOE activity." Buried therein is a crucial question: Are the lessee workers who perform non-DOE work members of the general public, DOE workers, or some new category of worker entirely? This is a crucial distinction when determining applicable safety requirements, liabilities, DOE involvement, and training requirements.[35]

The three DOE offices that are responsible for the program in one way or another — Worker and Community Transition, Environment Safety and Health, and Environmental Management — are still debating the issue.[36] They know it is a crucial one. For instance, according to Charles Lewis of DOE's ESH Oversight Office,

> It is our interpretation of DOE requirements that if these workers are classified as members of the public, then a re-evaluation of the Safety Analysis Reports for adjacent hazardous facilities [e.g., the TSCA incinerator] is needed, as the public is no longer at the site boundary.[37]

While the DOE debates and develops its policy for the protection of workers in leased facilities, the DOE is classifying the lessee workers at Oak Ridge as DOE general workers. In other words, the lessee workers are being permitted to receive up to 5 rem per year radiation exposure (stipulated in 10 CFR 835.202(a) for the "occupational exposure to general employees resulting from DOE activities").[38] This is 200 times higher than the EPA annual exposure limit for members of the general public from nuclear fuel cycle activities (25 millirem). Further, the standard is being applied to the lessee workers without the benefit of a rigorous radiation protection program including training, inspections, and thorough individual exposure monitoring. It also appears that the DOE is proceeding without the fully informed consent of the workers.[39]

*Thus the DOE, unregulated by an outside agency, is extending, through its reindustrialization program, unnecessary radiation risks to a whole new group of people without even the level of protection, training, or monitoring it requires of or affords to its own workers.*

There is no reasonable basis on which to classify lessee workers as anything but members of the general public so far as the level of radiation protection is concerned. Lessee workers are not employed by DOE, nor are they doing DOE work for a DOE contractor or sub-contractor. They are not classified as radiation workers outside of DOE's purview. Were that the case, the lessees would have to obtain a Nuclear Regulatory Commission license and the workers would have to be trained and protected accordingly. The only area in which lessee workers may reasonably be distinguished from the general public is the level of training, oversight, and protection afforded to them in order to ensure that their exposures stay within the limits allowed for the general public.

### Conclusions

The DOE is far from ready to lease contaminated facilities. It is doing so without a clear idea of who is responsible for worker safety and health and without adequate worker health and safety protection, or even an agreement about the standard of protection to be afforded to the workers. The DOE is thereby extending to new groups of workers its lamentable Cold War record of unnecessary exposures to health risks that are poorly documented. It appears not to have learned the lessons from the huge numbers of complaints of ill-health, the unexplained problems that still plague its workers (including those of its contractors), or the loss of trust and lawsuits that its past behavior has spawned.[40]

Moreover, the DOE is following its well-established sorry pattern of jumping into projects without proper preparation. In this case, it leased contaminated facilities three years ago at Oak Ridge, but still has not established clear accountability, legitimate compliance with the relevant 1994 law, or consistent and conservative rules for worker protection.

SEE **RUSH TO RENT** ON PAGE 7,
ENDNOTES ON PAGES 7-8

## RUSH TO RENT

FROM PAGE 6

### Recommendations

If the DOE decides to continue with reindustrialization, it must immediately implement measures to ensure the protection of the health and safety of the employees of lessee companies. The DOE should halt all further leasing and revisit all current leasing and reindustrialization activities while taking the following measures:

- Establish enforceable protection standards that classify lessee workers as members of the general public so far as maximum permissible exposure to radiation or other harmful substances is concerned. The applicable regulation as regards radiation exposure should be the EPA 25 millirem fuel cycle limit for the maximally exposed individual.
- Create clear regulations and guidelines under which all parties, including DOE and the lessees, can be held accountable for worker protection. Such regulations are necessary because the DOE is, through reindustrialization, allowing the general public in the form of non-DOE, non-radiation workers inside contaminated areas and buildings on a regular basis.
- Establish clear, continuing comprehensive external oversight of worker safety and environmental and public health protection. The process should include meaningful, early involvement of workers and the public. It should also ensure that adequate documentation of potential and actual exposures of the workers be kept so that the kinds of questions and uncertainties that have plagued workers at DOE facilities so far not be extended to lessee workers.
- Implement the Hall Amendment protocol for leasing DOE facilities, with the additional proviso that the 25 millirem dose limit to the maximally exposed individual should apply. The Hall Amendment implementation should include concurrence of EPA on DOE's leasing decisions and broad public and worker input into, and government openness about, the leasing process.

Until the DOE takes these steps, it should suspend the leases at contaminated Oak Ridge facilities and adequately compensate the lessees for damages that they would incur by having to move their operations and workers from leased facilities at Oak Ridge.

1 This phrase first appeared in the Draft *Special Review: Safety Management Evaluation of Facility Disposition Programs at the East Tennessee Technology Park*, by the Office of Oversight of US DOE Office of Environment, Safety and Health, July 10, 1997. The phrase was removed in the final version.

2 I would like to thank Mary Bryan, Lois Chalmers and Arjun Makhijani for their help on this article.

3 US DOE, Office of Environment, Safety and Health, Office of Oversight, *Special Review: Safety Management Evaluation of Facility Disposition Programs at the East Tennessee Technology Park*, September 1997, EH2PUB/09-97/05SR, p.33.

4 For a list of lessees, see the Oak Ridge Advantage website, http://www.bechteljacobs.com/reindust/advantage.htm.

5 DOE-Oak Ridge, "Reindustrialization" slide presentation, November 1998, slide 98-0824-R9 Revised 11/19/98.

6 US DOE, 1997, p.2.

7 US DOE, 1997, p.22.

8 According to Robert Brown of DOE-Oak Ridge, uranium permeated the building's structures when Oak Ridge gaseous diffusion plants were operational.

9 Laura Frank. Susan Thomas and Anne Paine, "Energy Department 'pushing safety aside' at Oak Ridge, EPA says," *The Tennessean*, September 28, 1997.

10 Correspondence with Charles Lewis, US DOE Environment, Safety and Health Office of Oversight, April 5 and 7, 1999.

11 Sanders, Charles L., *Toxicological Aspects of Energy Production* (Columbus Ohio: Battelle Press), 1986, p. 157-158.

12 "At Oak Ridge...Doctors Speculate Beryllium Exposure Likely at K-25," *Nuclear Weapons & Materials Monitor*, March 29, 1999, p. 13.

13 Core Group Report, *Pilot Project on OSHA External Regulation of DOE Facilities: Oak Ridge National Laboratory and East Tennessee Technology Park*, January 1999.

14 Correspondence with Robert Brown, DOE-Oak Ridge, April 19, 1999, and Oak Ridge Advantage website, http://www.bechteljacobs.com/reindust/advantage.htm.

15 10 CFR 835.602

16 Correspondence with Charles Lewis, 1999.

17 Correspondence with Robert Brown, April 6, 1999.

18 Correspondence with Charles Lewis, 1999.

19 Science Applications International Corporation, *Screening-level Human Health Risk Assessment for Building K-1401*, K/EM-565, December 1997, pp. 6-1 and 6-4.

20 Science Applications International Corporation, 1997, p. vii.

21 The 40-year dose is inferred form the 10-year figure for inhalation risk in a DOE document. See Science Applications International Corporation, 1997, pp. 6-1 and 6-4. The Environmental Protection Agency has raised concerns about Oak Ridge risk assessments, including DOE's use of 10- or 20- year exposure scenarios when the standard default assumption in EPA guidelines is 25 years for workers under the industrial scenario (see Letter to Susan Cange, Reindustrialization Liaison, DOE Oak Ridge Operations, from John Blevins, Oak Ridge Project Manager for EPA Region IV, October 23, 1998).

22 Science Applications International Corporation, 1997, p. 6-2 for estimates of risks from external exposure at the hot spots and Oak Ridge document number OR-99-142-0002 (attachment to Science Applications International Corporation memorandum to Ms. Lesley Cusick, Bechtel Jacobs Company LLC, General Order 78B-99421C, Subcontract 12K-MCL60V, March 8, 1999) for an estimate of risk from external exposure that is ten times lower than on p. 6-2.

23 Shawn Terry, "DOE Moves Reviews of Leasing Decisions from Field Office to ES&H," *Inside Energy*, January 25, 1999.

24 Core Group Report , 1999, p. 49, and correspondence with Charles Lewis, 1999.

25 Correspondence with Robert Brown, April 6, 1999.

26 Oak Ridge Advantage website, http://www.bechteljacobs.com/reindust/advantage.htm.

27 US DOE/US EPA Memorandum, "Joint DOE/EPA Interim Policy Statement on Leasing Under the "Hall Amendment," June 23, 1998.

28 DOE Memorandum to Jennifer Fowler, Oak Ridge Operations Office Chief Counsel, from Eric J. Fygi, US DOE Acting General Coun-

SEE **RUSH TO RENT** ON PAGE 8

## CONSIDERING

FROM PAGE 2

drilled into the mountain. The Waste Isolation Pilot Plant (WIPP) deep salt bed repository has been approved to receive TRU waste by the Environmental Protection Agency, but still lacks a permit for the non-radioactive hazardous wastes present in most containers.[1] Granite and clay sites are being investigated in countries such as Sweden and France.

There are three principal difficulties with geologic repositories:

1. It is likely that some radioactive wastes will leak from the canisters and other barriers built to contain them.
2. Prediction of the performance of the repository over very long time periods is very difficult.
3. It is essentially impossible to guarantee that there will not be inadvertent or deliberate human intrusion.

These problems can be addressed to varying degrees by a sound site selection process, by adequate research and development on engineered barriers, and by carefully consideration of the causes of human intrusion. Let us address the last question first.

One of the thorniest issues relating to human intrusion is whether and how to warn generations far into the future of the dangers of radioactive waste. Warning systems to keep people away have dubious utility, at best, and encourage unwarranted complacency, at worst.[2] Furthermore, techniques to warn future generations against inadvertent intrusion would draw attention to the disposal site and increase the danger of deliberate intrusion to get at plutonium or other materials in the waste.

The chance of deliberate intrusion can be minimized by designing the repository and engineered barriers so that it would be technically and economically far more difficult to recover spent fuel and bring it to the surface than to build a new nuclear reactor to produce plutonium. The chance of deliberate intrusion is also reduced if there are no permanent markers warning of the disposal site and its contents.

The most important safeguard against inadvertent intrusion is to select a site where it is highly unlikely that human beings will search for resources. Following this logic, the best guarantee against intrusion is to select a site where:

- the water resources at the repository location or in its vicinity are highly unlikely to be used, for instance because of poor quality, so that their contamination does not present a probable hazard to human beings;
- there are no known commercially-important resources at the site or in its vicinity;
- essentially all elements and geologic minerals are more easily and abundantly available in the general geographic region than at the repository location or in its vicinity.

The Yucca Mountain site fails on the first and third counts. Water is generally scarce in the region, while groundwater is available and of high quality. Although the water under the repository site itself lies under a mountain, groundwater in the immediate vicinity of the site is more accessible to drilling, making intrusion a real possibility. Further, groundwater as near as 20 miles from the site, in Amargosa Valley, is currently used for irrigation. Yucca Mountain is also located in a mineral rich area. The mountain itself has not been exploited for mineral resources, but silver and gold mining are carried out within sight of it.[3] The WIPP site fails the second criterion because there are petroleum and potash resources in the vicinity.

A recommendation for study by a 1983 panel on waste isolation of the National Research Council of the National Academy of Sciences (NAS-NRC) appears to meet these criteria[4] (but fails on other grounds — see below). The suggested type of site would be in a granite layer containing brackish groundwater that lies under a sedimentary aquifer. Such sites are found in some locations near the eastern seaboard of the United States, where surface fresh water is relatively abundant.

SEE **CONSIDERING** ON PAGE 9
ENDNOTES ON PAGE 20

## RUSH TO RENT

FROM PAGE 7

sel, "Leasing of Department of Energy Property," March 27, 1998.

29 DOE-Oak Ridge, 1998, slide ETTP/GA 99-0014.

30 Letter to Ralph Hutchison, Oak Ridge Communities Allied, from Timothy Fields, Acting Assistant Administrator, USEPA Office of Solid Waste and Emergency Response, February 22, 1999.

31 Letter to Susan Cange, Reindustrialization Liaison, DOE Oak Ridge Operations, from John Blevins, Oak Ridge Project Manager for EPA Region IV, October 23, 1998.

32 Letter to Timothy Fields, Acting Assistant Administrator, US EPA Office of Solid Waste and Emergency Response, from Oak Ridge Communities Allied, November 2, 1998.

33 Larisa Brass "EPA/DOE to resolve leasing," *Oak Ridger*, April 8, 1999.

34 Telephone conversation with Richard Miller, Paper, Allied-Industrial, Chemical & Energy Workers International Union, March 30, 1999.

35 US DOE 1997, p. 21.

36 Correspondence with Bob DeGrasse, Director, Office of Worker and Community Transition, US DOE, March 26, 1999.

37 Correspondence with Charles Lewis, 1999.

38 *Code of Federal Regulations, Part 500 to End* (Washington, DC: Government Printing Office), 1997, pp. 423-424.

39 Core Group Report , 1999, p. 49.

40 See *SDA* vol. 5 no. 3, "Fernald Workers' Radiation Exposure," October 1996, *SDA* vol. 6 no. 2, "Worker Radiation Dose Records Deeply Flawed," November 1997, and Arjun Makhijani, Howard Hu and Katherine Yih, ed., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects*, (Cambridge, Massachusetts: MIT Press), 1995, p. 262-263.

**CONSIDERING**
FROM PAGE 8

Since there would be a fresh water aquifer above the site, intrusion to get at brackish water would be highly unlikely. As regards other resources, granite is abundantly available close to the surface in eastern locations, so that drilling for any other known resources in deep granite is also unlikely.

However, human intrusion is only one of the concerns that must be addressed in a repository program. In addition, the repository (or any other disposal means) must meet environmental, health and technical criteria. Some of the essential ones are:

- The repository and engineered barriers should each be able to meet strict health-based performance criteria as separate systems in order to provide a minimal element of redundancy. This is essential since there will remain considerable uncertainties in estimating performance of either system over long periods of time.
- Repository performance, including that of the engineered barriers, should be characterizable to a degree to allow statements about compliance with strict health protection standards to be made with a high degree of confidence.
- The site should not have the potential to destroy or seriously disrupt unique ecological resources. For instance, putting unique species at risk would be unacceptable.

In addition to the many problems already mentioned, Yucca Mountain also fails on the first of these criteria because the geology is not expected to provide a meaningful barrier in the long term. The one specific location suggested by the NAS-NRC panel is unsatisfactory because it fails to meet the third criterion. It would be near at or near the Chesapeake Bay, one of the richest and most sensitive natural environments in the United States. The introduction of vast quantities of nuclear waste and the accompanying large-scale construction in the region would be highly disruptive of a unique ecological and economic resource.

Finding an appropriate repository site is a very difficult and complex process that must balance a wide range of considerations, as is illustrated by the preceding discussion. Thus, it is very premature at this time to select actual repository sites or even to engage in a site selection process. Much more basic research on various geologic settings is needed before sites can be scientifically screened. Further, repository types need to be considered in tandem with the development of engineered barriers.

IEER's recommendations for the US repository program are:

1. Convert WIPP and Yucca Mountain into world-class centers for research on geologic disposal, testing of materials for engineered barriers, etc., using only non-radioactive analogs. This would be contingent on consent by the state of New Mexico for WIPP, and the state of Nevada and the Western Shoshone people in the case of Yucca Mountain. WIPP and Yucca Mountain would be *permanently* off the table as potential repository sites because they are poor repository locations. Waste already placed in WIPP should be removed from it since it is a poor site and since the presence of radioactive wastes in it will limit and compromise research activities that would serve a sound long-term management program.
2. Expand and intensify research into the study of natural environments in which radioactive materials have been contained for millions of years and couple this work to an engineering program of developing analogs of these natural materials. The objective would be to design and manufacture engineered barriers around the spent fuel that would mimic these natural materials and environments.
3. Study various kinds of repository locations by doing theoretical research, computer modeling, and laboratory, geologic and other field work for ten to fifteen years without any attempt to rank or screen these locations as potential repository sites. Waste would be stored as safely as possible on site or as close the point of generation as possible during this time.

**Sub-seabed disposal**

Sub-seabed disposal has been studied to a much lesser extent than geologic repository disposal. It is important to distinguish sub-seabed disposal from sea dumping of radioactive waste. Sea dumping involves the disposal of waste into the water, where it is certain to become dispersed. By contrast, sub-seabed disposal would place the waste beneath the sea floor. If successfully accomplished, the waste would not disperse into the oceans.

There are two approaches to sub-seabed disposal as it has been considered so far:

- put the waste in holes drilled tens of meters deep into the ocean floor
- put the waste in canisters shaped like long projectiles that penetrate into the ocean floor. The penetration depth in soft clays may be several tens of meters.[5]

A site in the North Pacific Ocean with 100 million square kilometers of ocean floor covered with soft red clays up to 100 meters deep has often been mentioned as a possible site (see figure 1).[6]

The main advantage of sub-seabed disposal relative to geologic disposal is that large radiation doses via the drinking water pathway are highly unlikely. Water used for drinking and irrigation is generally regarded as the

SEE **CONSIDERING** ON PAGE 10,
ENDNOTES ON PAGE 20

## CONSIDERING

FROM PAGE 9

most important radiation exposure pathway that would result from geologic disposal.[7] However, radiation doses via the food pathway are possible. Based on current technology, deliberate human intrusion would be far more difficult than with geologic disposal. Given that rapid technological change is likely to continue, deliberate intrusion might be possible, though the lack of markers or any other surface manifestations should make this less likely than for land-based repositories. Inadvertent intrusion would appear to be far more unlikely under the ocean, especially in areas away from coastal areas and where there are no readily accessible seabed mineral resources.

Because less research has been done into sub-seabed disposal, less is known about the potential problems with this storage method. However, troubling questions have been raised. For instance, oceanographers Hessler and Jumars have noted that while the density of living matter in the deep sea is low, life there is very diverse. Several factors promote this diversity of life in the deep-sea environment, notably the fact that it is very stable:

> "Such stability minimizes the likelihood of extinctions even for species maintaining extremely low population densities, and thereby allows the diversity of communities to build to high levels....
>
> "While no one has yet measured the tolerances of abyssal [deep-sea] organisms, it is almost a certainty that they can adjust to only a small degree of environmental change....Thus any kind of human activity on the deep-sea floor — be it waste disposal, nodule mining, or anything else — is likely to have a far more deleterious effect than would a comparable disturbance in shallow water."[8]

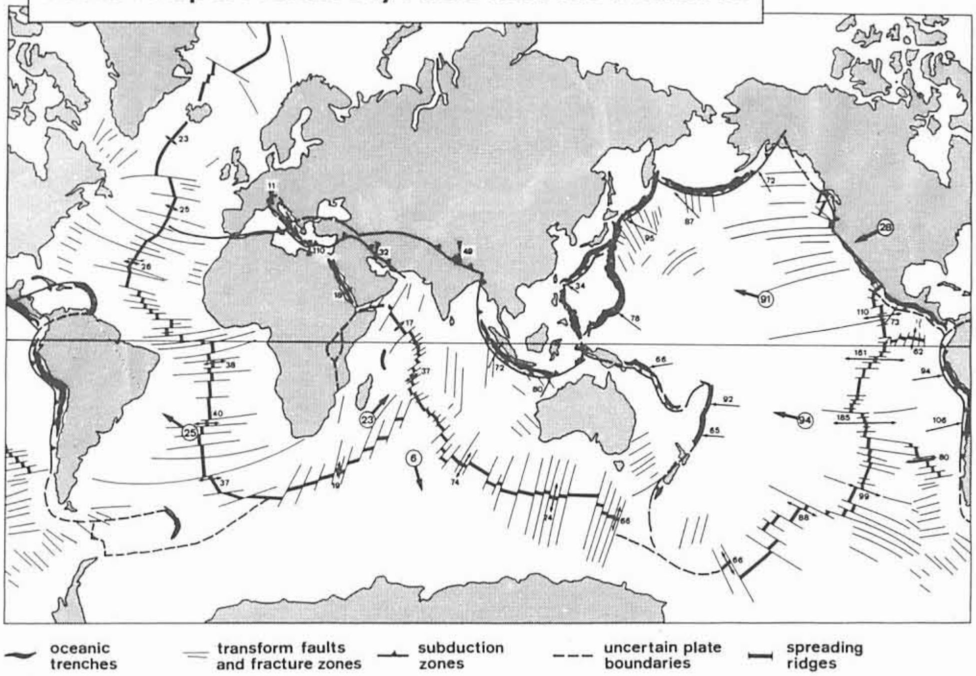
In the long run, questions of isolation from the human environment in the case of sub-seabed disposal may be broadly similar to those facing geologic disposal. Transportation, waste emplacement, and licensing also pose significant challenges. Finally, the international convention against sea dumping of radioactive wastes may prohibit sub-seabed disposal.

Given the potential vulnerability of life in the deep-sea to human activity, sub-seabed disposal cannot be viewed as a "solution" to the waste disposal problem. But its relative problems may not be more severe than those with geologic repositories, though the specific issues are somewhat different. Hence, at the present time, sub-seabed disposal should be allocated significant research resources. These resources should not be used to add radioactive materials into the oceanic or sub-seabed environment. International collaborative sub-seabed disposal research could be a major component of the conversion of Cold War naval apparatus in the nuclear weapons states to peaceful purposes.[9]

One disadvantage of sub-seabed disposal is that it would involve disposal in the global commons. Countries that have made inadvisable decisions regarding nuclear power and weapons would be able to dispose of waste without taking the commensurate domestic liability for the problem. To make matters worse, countries that have not generated high-level radioactive wastes would share in potential adverse consequences. The use of sub-seabed disposal or any other international approach should be considered only in the context of the complete and irrevocable phase-out of nuclear power and of fissile materials and tritium production for weapons purposes.

SEE **CONSIDERING** ON PAGE 11, ENDNOTES ON PAGE 20

FIGURE 1 **Map of Present-Day Plates and Plate Boundaries**




**Source:** A.G. Milnes, Geology and Radwaste, 1985, p. 63. Reprinted with permission of Academic Press.

## CONSIDERING

FROM PAGE 10

### Disposal outside the biosphere

There are two alternatives for disposal of nuclear wastes outside the biosphere: either above it, in space, or below, beneath the Earth's crust in the upper mantle.

The first is impractical and should be rejected due to the large volumes of waste involved, due to both cost and safety concerns. The remaining option is disposal beneath the biosphere. It is difficult to define an exact lower boundary to the biosphere, because there are interactions between the various layers of the Earth. For instance, volcanic eruptions bring up magma from outside the biosphere into it. The operational definition of "biosphere" for the purposes of nuclear waste disposal would itself have to be the subject of considerable research. Two somewhat different definitions may be satisfactory:

- deep regions of the Earth's crust where there is no water even in the pores of the rocks.
- stable portions of the upper mantle (which lies below the Earth's crust) that do not exchange material with the biosphere on time scales smaller than tens of millions of years.

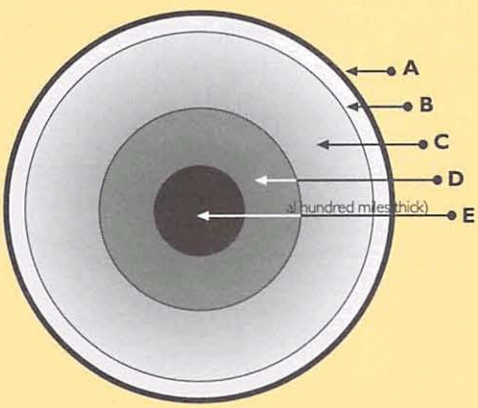
Figures 1 and 2 show the various layers of the Earth. The Earth's crust is roughly 5 to 10 kilometers thick beneath the oceans; by contrast, it is between 20 and 70 kilometers thick under continental areas.[10] The boundary of the Earth's crust and the upper mantle — called the Mohorovicic discontinuity or Moho for short — is characterized by a sudden increase in density with depth. This enables the upper mantle to be identified as a distinct layer geologically (and hence also for disposal). In some areas, the rock in the upper mantle is in a molten or semi-molten state, but in most areas it is solid. Investigation of the layers of the Earth where boreholes cannot yet be drilled is carried out by indirect methods such as study of changes in the velocities of seismic waves at boundaries between layers.

Disposal in the uppermost region of the mantle would have some of the same characteristics as deep borehole disposal in the Earth's crust.[11] In the case of disposal in the upper mantle, the waste containers would be lowered into extremely deep boreholes extending below the Earth's crust. The boreholes would be drilled in a geologically stable area, that is, away from areas where tectonic plates converge (at the continental margins) or diverge (as, for instance, in the mid-Atlantic and East Pacific ridges).

Stable areas in the upper mantle may be able to keep the waste out of the biosphere for millions of years,

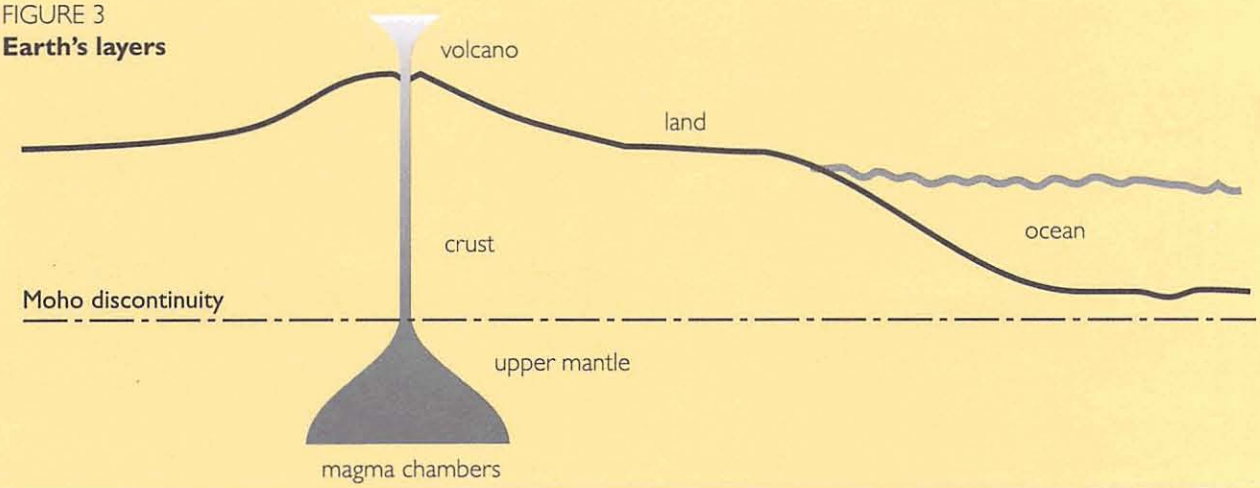
SEE **CONSIDERING** ON PAGE 20

FIGURE 2
**Earth, cross section**




A – **Earth's crust** (Few tens of miles thick)
B – **Upper Mantle** (Several hundred miles thick)
C – **Mantle** (~1000 miles thick)
D – **Outer core**
E – **Inner core**

FIGURE 3
**Earth's layers**



# Some Evidence of Yucca Mountain's Unsuitability as a Repository

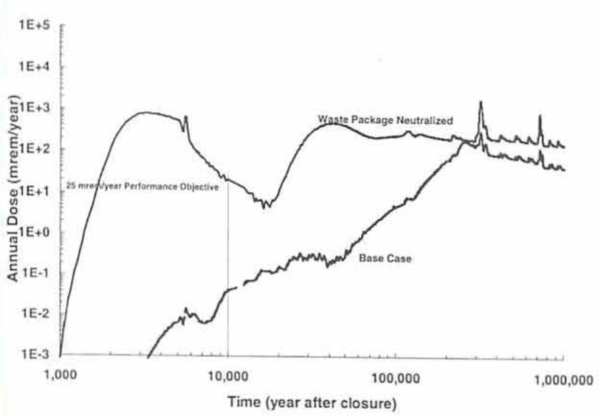
The Yucca Mountain Site is unsuitable as a geologic repository. The graphs published here were prepared by the DOE in response to a request from the Nuclear Waste Technical Review Board, an oversight body established by Congress. The graphs illustrate the contribution of various elements to waste isolation by evaluating the effect of each on doses.

The dose to the public without a particular element in the system is compared to the "baseline case" which includes all the elements of the system. For example, Graph A shows the projected increase in doses that would occur without the presence of the waste package (ie: the canister). It is clear from the charts that the canister is by far the most important element in preventing doses to the public, and that the fuel itself is also important in containment. This is because the fuel is in ceramic form that would be expected to resist degradation.

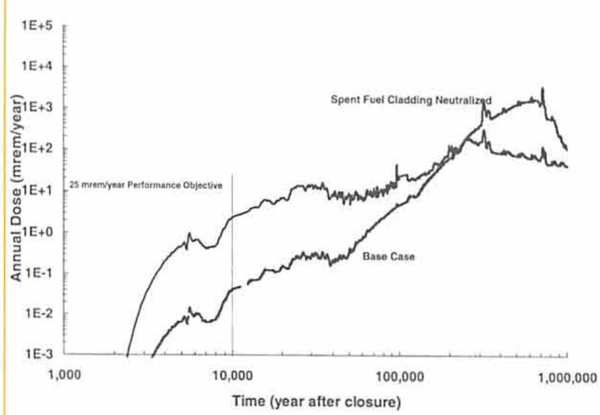
The charts show that the geologic elements of Yucca Mountain are ineffective relative to the waste package. The main aim of the repository program so far has been to select a site at which the geology would be the main element in waste isolation. That aim is defeated by selecting Yucca Mountain. The response of the Nuclear Regulatory Commission to evidence of Yucca Mountain's geologic unsuitability has been to throw out its old standards, which stressed repository containment, and replace them with new ones that allow the canister to fulfill this function.

SEE **YUCCA MOUNTAIN** ON PAGE 13

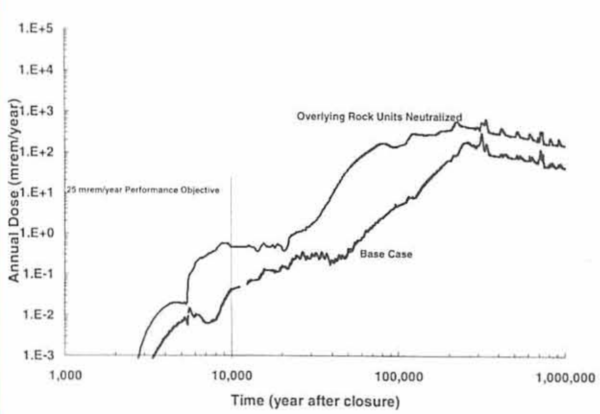
Graph A: **Neutralize Waste Package**



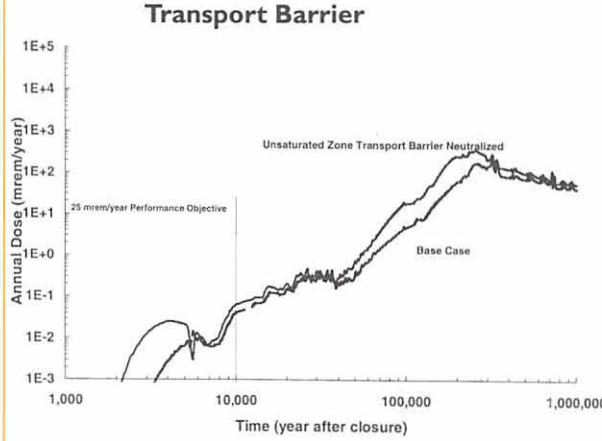

Graph B: **Neutralize Spent Fuel Cladding**




Graph C: **Neutralize Overlying Flow Barriers**




Graph D: **Neutralize Unsaturated Zone Transport Barrier**




Source for all graphs: U.S. DOE Office of Civilian Radioactive Waste Management, "NWTRB Repository Panel meeting: Postclosure Defense in Depth in the Design Selection Process," presentation for the Nuclear Waste Technical Review Board Panel for the Repository, January 25, 1999.

## YUCCA MOUNTAIN

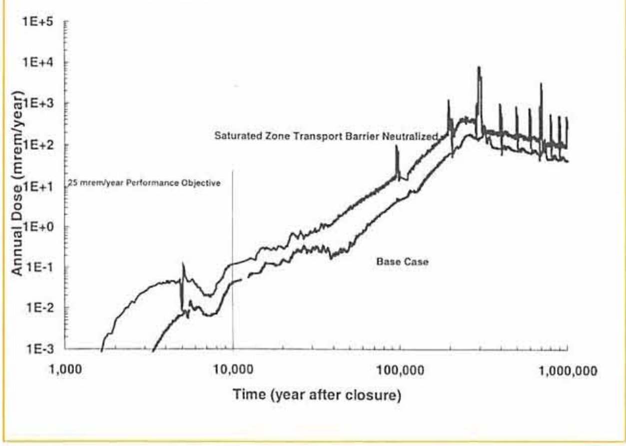
FROM PAGE 12

This is clearly an unacceptable response from the point of view of safeguarding public health. Because of grave uncertainties about performance over the very long term, it is important to build several levels of redundancy into any geologic storage program. For example, not only do analyses show the potential lack of effectiveness of Yucca Mountain geology in containing waste, but serious questions have also been raised as to whether the canister will perform as projected, and indeed, whether the performance of the canister can be characterized with confidence. Here is what the DOE's peer-review panels have had to say on these issues:

> "Alloy C-22 [a corrosion-resistant metal (CRM) favored by the DOE for waste canisters] is susceptible to localized corrosion only when wet in a critical temperature range. If C-22 remains passive in this range, its anticipated life, prior to penetration, is thousands of years. If it is not passive, then its life, prior to penetration, is as little as a few tens of years...The water seepage pattern during the period when a waste package is in the critical temperature range for CRM corrosion is not well defined.
>
> "This is when major damage can occur. There is a need to determine the critical temperature range, and the times in this range when different scenarios can occur."
>
> — Chris G. Whipple, Robert J. Budnitz, Rodney C. Ewing, Dade W. Moeller, JoeH. Payer, and Paul A. Witherspoon, *Yucca Mountain Total System Performance Assessment, Third Interim Peer Review Panel Report*, 1998, pp. 20–22.

> "With the benefit of hindsight, the Panel finds that, at the present time, an assessment of the future probable behavior of the proposed repository may be beyond the analytical capabilities of any scientific and engineering team. This is due to the complexity of the system and the nature of the data that now exist or that could be obtained within a reasonable time and cost."
>
> "...assessment of the seepage and of the number of waste packages that will experience water drips is highly uncertain. For these reasons, it is not clear to the Panel that the present approach correctly captures the seepage behavior of an individual drift.
>
> "The large uncertainty in the seepage analysis is unfortunate, because seepage into the drifts is one of the most sensitive parameters in the dose estimates presented in the TSPA-VA. Given the uncertainties described above, the long term effect of the percolating rate on seepage cannot be calculated with a reasonable degree of accuracy. In addition, the percolation rate is itself uncertain due in part ot uncertainties in long-term climate predictions."
>
> —Final Report, *Total System Performance Assessment*, Peer Review Panel, February 11, 1999, Prepared by: Bob Budnitz, Rad Ewing, Dade Moeller, Joe Payer, Chris Whipple, and Paul Witherspoon, pp. 1, 6.

Graph E: **Neutralize Saturated Zone Transport Barrier**




Further, the DOE has settled on a "hot repository" model, in which waste canisters are packed tightly together in order to keep the repository temperature well above the boiling point for a long period of time. However, a "hot repository" could change the rock structure of the geologic system in ways that would be difficult or impossible to predict, and therefore increases risk even further. A repository that was not hot enough to keep moisture out for prolonged periods of time would run the risk of a humid environment rapidly corroding the canisters, as indicated in one of the quotes above. Such an environment also threatens rapid degradation of borosilicate glass, which has been chosen as the waste form for solidifying high-level military waste.[1]

Thus, the DOE's own assessments and other evidence indicate that Yucca Mountain is not capable of geologically isolating radioactive waste from the environment. It is an unsound repository location and should be ruled out before more money is needlessly expended.

### Note

1 Arjun Makhijani, *Glass in the Rocks: Some Issues Concerning the Disposal of Radioactive Borosilicate Glass in a Yucca Mountain Repository*, IEER, January 29, 1991.

# INTERNATIONAL REPOSITORY PROGRAMS

| Country | SNF Policy | Repository Type | Site Selected |
|---|---|---|---|
| **Belgium** | Foreign Reprocessing | Clay | |
| **Canada** | Storage | Crystalline Rock | No |
| **China** | Domestic Reprocessing (small plant being built) | Unknown | NW China or Gobi desert |
| **Czech Republic** | Storage | Undetermined | No |
| **Finland** | Storage | Crystalline Rock | 3 Candidates |
| **France** | Reprocessing | Clay or Granite | 1 Candidate; searching for a 2nd |
| **Germany** | Foreign Reprocessing and SNF Storage | Salt Dome | Gorleben |
| **India** | Domestic Reprocessing | Granite | Candidate sites list finalized |
| **Italy** | Foreign Reprocessing and SNF Storage | Undetermined | No |
| **Japan** | Foreign and Domestic Reprocessing | Clay and Crystalline Rock | |
| **Korea** | Storage | Undetermined | No |
| **Russia** | Reprocessing; liquid HLW stored in above-ground reservoirs and injected underground | Granite; Permafrost, Salt, Tuff | No |
| **Spain** | Foreign Reprocessing and SNF Storage | Granite, Salt or Clay | No |
| **Sweden** | Centralized Interim Storage | Crystalline Rock | 5–10 Candidate Sites |
| **Switzerland** | Foreign reprocessing and SNF Storage | Crystalline Rock or Clay | No |
| **Taiwan** | Storage (may undertake foreign reprocessing) | Unknown | No |
| **UK** | Reprocessing | No | No |
| **USA** | Storage | Volcanic Tuff | Yucca Mountain |

**HLW:** high-level waste **SNF:** spent nuclear fuel
**URL:** underground rock laboratory
**Unknown:** Information was not available.
**Undetermined:** No decision has been made by appropriate national authority.

**Official Nuclear Waste Websites:**
US DOE Radioactive Waste Management Pages *http://www.rw.doe.gov*
Nagra (Switzerland) *http://www.nagra.ch*
SKB (Sweden) *http://www.skb.se*
NIREX (UK) *http://www.nirex.co.uk*
IAEA *http://www.iaea.or.at/worldatom/*

# INTERNATIONAL REPOSITORY PROGRAMS

| Timeframe | Underground Research | Current Status | Comments |
|---|---|---|---|
| 2015: Detailed studies<br>2030: Open | Yes | On-going under ground research | |
| 2025: Open | Yes | Recently completed environmental review | |
| Unknown | Unknown | Unknown | |
| Undetermined | No | Conceptual study for URL | |
| 2000: Site selected<br>2020: Open | Yes | | |
| 2020: Open | Proposed (+ foreign) | Plans to open 2 URLs at candidate sites | Study also ongoing into transmutation & above-ground permanent storage options |
| 2005: Site suitability<br>>2013: Open | Yes | Continuing with site evaluation of Gorleben? | There is a highly contested interim storage facility at Gorleben |
| ~2020 | Yes | Final site selection process begun | |
| Undetermined | No | No indication that active repository research is being undertaken | |
| 2000: Site selection phase begins | Use of foreign labs | Generic guidelines established; lab research program | |
| Undetermined | No | Technical studies; assessment methodology & disposal concept being developed | |
| Unknown | Planned | Criteria for site selection established, technical studies ongoing | Has injected HLW into wells |
| 2020: Open | Use of foreign labs | R&D on both engineered and geologic barriers | |
| >2003: Site selected<br>>2008: Open | Äspö hard rock lab | Candidate site evaluated for feasibility; 2 will be chosen for surface level study; 1 of those will be chosen for detailed investigation | Extended Storage Option |
| After 2020 | Yes | Active R&D program | |
| 2016: Site Selection<br>2032: Rep. Open | Use of foreign labs | | |
| Undetermined | Use of foreign labs | No active repository research program is evident | |
| 1998: Viability Assessment Issued | Yes | On-going effort to open Yucca Mountain. Repeated proposals to open central interim storage site | |

**SOURCES:** Parliamentary Office of Science and Technology 1997. *Radioactive Waste — Where Next?* London: November 1997; Don J. Bradley. *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union.* Columbus: Batelle Press, 1997; Nuclear Energy Agency 1998. *NEA Nuclear Waste Bulletin 13: 1998.* Organization for Economic Cooperation and Development Nuclear Energy Agency; J.P. Amaya et. al. 1997. *International Waste Management Fact Book.* Richland, WA: Pacific Northwest National Laboratory, October 1997. PNNL-11677; Website of Posiva Oy (Finnish nuclear waste disposal company), http://www.tvo.fi/posiva.htm

## SHORT TERM

FROM PAGE 1

While critics, including the present writer, have often pointed to the flaws of the current program, they have, at best, presented only sketchy alternatives for the long-term management of these wastes. If these problematic projects are to be stopped, it is essential that there be wide public debate on a detailed alternative now. The DOE's failure to meet two politically-driven deadlines has created increasing pressure to do something with the waste, even if it increases long-term risks:

- Nuclear utilities have filed lawsuits against the DOE for failing to begin taking charge of their spent fuel in January 1998, despite a commitment to do so as part of its implementation of the 1982 Nuclear Waste Policy Act. In the utilities' view, a "solution" is simply to take the waste or at least the liability for it immediately out of their hands.[5] If the DOE is forced to pay even part of the billions of dollars of civil penalties that utilities are asking in these lawsuits, there will be even more political pressure for the government to assume liability for the waste now at operating nuclear power plants. Given the mess that the DOE has made at the nuclear weapons sites and its problems with managing its own irradiated fuel, this would be a grave step backward in nuclear waste management.
- The DOE made a commitment to take transuranic waste out of Idaho, where most containerized TRU waste is stored, to a repository by 1980. Missing that deadline has given rise to a series of political crises, such as a governor of Idaho threatening to close down its border to incoming waste. Among other things, spent fuel from naval nuclear reactors is sent to Idaho for storage. The DOE has now put transuranic waste in WIPP, even though it aggravates rather than solves problems relating to TRU waste management (see "Considering the Alternatives," page 1).

Storage of spent fuel and TRU waste on site for a few decades is feasible and can generally be done relatively safely, if the industry and regulatory authorities pay due attention to the safety issues involved. Current practice leaves a good deal to be desired. The design and licensing of casks should take account of

SEE **SHORT TERM** ON PAGE 17,
ENDNOTES ON PAGE 19

### REJECTED HIGH LEVEL WASTE MANAGEMENT METHODS[1]

| Waste Disposal Method | Description | Reasons for Rejection |
|---|---|---|
| **Liquid Injection[2]** | Injection of liquid waste (sometimes mixed with grout) into wells hundreds of meters deep. | • difficult to assess waste isolation<br>• lack of engineered barriers<br>• migration of contaminants through soil to water, possibly rapid |
| **Rock Melting** | Fill deep mined cavity with high-level waste so that surrounding rock is melted and encapsulates waste. | • high uncertainty about radionuclide migration<br>• difficult to assess waste isolation<br>• interaction of melted rock with host rock unknown<br>• specific techniques not developed<br>• inapplicable to older reprocessing waste with low heat |
| **Ice Sheets** | Direct melting of waste through ice to bedrock or surface facility pushed down through ice due to accumulating snow and ice | • migration of ice<br>• formation of icebergs with waste<br>• durability of waste container system unknown<br>• pathways for waste migration unknown |
| **Shoot it into Space** | Place waste into space or put rocket on collision course with sun. | • danger of accident during launch<br>• large volumes of waste would entail many flights resulting in higher risks and higher costs.<br>• reduction of volume to dispose only long-lived radionuclides requires separation technologies, which pose serious environmental and non-proliferation risks. |

**Source:** Office of Technology Assessment 1985. *Managing the Nation's Commercial High-Level Radioactive Waste* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-O-171, March 1985).

[1] All of these methods were rejected by the US Department of Energy in the 1970s.

[2] See Fioravanti and Arjun Makhijani 1997. *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, IEER Report, October 1997; and McCarthy et. al. "Lanthanide Field Tracers Demonstrate Enhanced Transport of Transuranic Radionuclides by Natural Organic Matter." *Environmental Science and Technology*. Vol. 32, No. 24. December 15, 1998.

## SHORT TERM

FROM PAGE 16

the need for on-site storage for a period of several decades, possibly up to about 100 years.

But on-site storage is not a sound strategy for the long term. It risks a host of problems, including the possibility of reprocessing, social instability, leaks and accidents, or destruction of waste storage containers by natural disasters or terrorism. There is also a high potential for neglect in economically difficult times. The problem of neglect may become more serious after the utility has shut down the reactor since the plant would not be generating any more income.

### Policy framework

We take as a starting point that WIPP and Yucca Mountain will not be used as repositories, because they are inappropriate technically and environmentally. Moreover, Yucca Mountain is on disputed territory. It is on the land of the Western Shoshone people that the US government claims it has obtained from them. But the Western Shoshone National Council does not recognize the US government's ownership claim as valid. Yet the DOE, Nuclear Regulatory Commission and the Environmental Protection Agency have failed to address this crucial issue.

Stopping WIPP and Yucca Mountain as repository projects need not be equivalent to throwing away the investment in them. These two facilities, along with several others around the world, could be used for scientific investigation of problems central to the concept of geologic repository disposal of waste (see below). But it is essential to stop poor repository programs and quick-fix approaches like hastily putting or exporting the waste somewhere if resources are to be freed up for a sound program of long-term waste management.

The need to separate long-term management from short-term political pressures is illustrated by the triumphalism that has accompanied sending some Los Alamos waste canisters (which contain wastes from a National Aeronautics and Space Administration program of plutonium-238-powered thermo-electric generators) to WIPP. The claim is that such placement represents a "solution" to the TRU waste problem. However, the only problem it "solves" is the creation of physical and political room for the DOE to create more TRU waste from new weapons production.

The technical goal of any disposal program is to isolate radioactive waste as completely as possible from the human environment for periods of time in which the waste is expected to remain dangerous. Depending on the criteria adopted, the relevant periods for high-level wastes are likely to extend to hundreds of thousands or even millions of years.

The goal of protecting human health and the environment for very long periods must be achieved within a specific non-proliferation constraint. Technologies that result in (or could easily be modified to result in) the separation of weapons usable materials, such as accelerator transmutation of waste, should be rejected. Even if the intent of these technologies is to manage nuclear wastes, their development involves proliferation risks that are too great.[6]

In order to separate the controversy of the future of nuclear power from waste management policy, spent fuel from existing nuclear power plants beyond their presently licensed lifetimes or from new nuclear power plants should be excluded by law from federal assumption of waste management liabilities. Future nuclear power plant owners and licensees should bear the full liability for the waste they produce. Similarly, the Pentagon as well as the Defense Programs portion of the DOE should bear the full liability for waste generation attributable to future production of nuclear weapons or weapons-usable materials.

The development of a long-term management approach that will be technically sound is likely to take several decades. Therefore, measures to manage the wastes are needed in the interim. Necessary interim management steps are:

1. Stabilization of threatening wastes, such as buried TRU waste and liquid high-level waste. In-situ methods should be ruled out since they are unreliable and could create more clean-up problems in the future.
2. Reclassification of waste to reflect longevity and hazard so that wastes of comparable hazard can be managed similarly.[7] This will result in joint management in a single long-term program of TRU waste, spent fuel, high-level reprocessing waste, and certain other highly radioactive wastes, such as some reactor internal parts after decommissioning.
3. Scientific and technological investigations of alternative long-term disposal approaches to a degree sufficient to make comparisons for the purpose of elimination.
4. Development of engineered barriers that mimic natural materials and structures that retard the migration of radioactivity for millions of years or more.
5. A firm commitment against reprocessing of spent fuel.
6. Storage of spent fuel, stabilized TRU waste, and other waste of comparable hazard and longevity as safely as possible on site or as close to it as possible for several decades.[8]

### Financial, legal, and non-proliferation concerns

Of the steps cited above, the last, storage of spent fuel on site or close to it, may be the most controversial in the context of a restructured long-term waste management program. Nuclear utilities have pushed

SEE **SHORT TERM** ON PAGE 18,
ENDNOTES ON PAGE 19

## SHORT TERM

FROM PAGE 17

hard for a Monitored Retrievable Storage (MRS) site away from the reactors.[9] The arguments in favor of a remote site that are put forward are:

1. It is safer to store spent fuel at one site rather than at dozens.
2. Neglect, poor management, or lack of funds may cause unforeseen problems with on-site storage once the reactors are no longer in operation.
3. The US government promised to begin taking charge of the waste by 1998 and has not done so, despite the billions of dollars that nuclear utility ratepayers have paid into the federal government's Nuclear Waste Fund.

The first statement is often made by industry as if it is so obvious that it needs no analysis or proof. However, the reality is that there will be many storage locations for decades even if an MRS is built because many reactors are likely to remain in operation for over ten years. Fuel must be stored at the reactor site for at least five years prior to transport. Moreover, moving the waste before any long-term management solution is decided upon carries a host of new risks arising from:

- transportation of the wastes to an MRS location
- greater pressure to open an inappropriately-located repository at the MRS location
- the possible need to transport wastes again should a repository not be opened at the MRS location
- temptations to reprocess the spent fuel that will all be at one location, causing more pollution and proliferation risks
- safety problems associated with loading, unloading and reloading canisters
- hasty decisions regarding canisters that should be far more carefully made
- greater pressure to re-license reactors because storage space is available for spent fuel.

These risks are both unnecessary and are qualitatively more serious than storage of spent fuel at reactor sites, which have, after all, been licensed for operation of reactors that generally carry far greater safety risks than spent fuel storage.

Some of the financial and legal arguments of the utilities do have merit. The DOE did sign contracts with them to begin taking charge of the waste in 1998, although it was done as part of deadlines in the 1982 Nuclear Waste Policy Act that were set without reference to environmental protection or sound nuclear waste management. Moreover, the problem of spent fuel management after a reactor is shut down is a serious one.

These issues can be addressed within the framework of on-site storage. First, the federal government should use monies from the Nuclear Waste Fund to pay for additional on-site storage necessitated by delays in the repository program. The time at which a nuclear power plant runs out of storage space for spent fuel is an appropriate time to consider alternatives to its continued operation, since building new storage requires significant new regulatory and economic decisions. The issue of management of highly radioactive waste (existing and that in the "pipeline" from current reactor license lifetimes) after reactors are shut down can be addressed by the creation of a federal corporation for management of highly radioactive waste. This corporation would take charge of all spent fuel at closed reactor sites and safeguard it until a long-term program is in place. The same corporation would be responsible for the development of the long-term program. (See article on institutional reform, page 21.)

Finally, some of those who put a high priority on non-proliferation have suggested that opening the Yucca Mountain repository is desirable to preclude reprocessing in the United States and to limit the build up of plutonium stocks. This argument would have more merit if the opening of a repository were tied to a phase-out of nuclear power. However, that is not the case. In fact, it has been suggested that Yucca Mountain be kept open for 300 years in order that the plutonium might be extracted in case it was required as a nuclear fuel.[10] Further, the current build-up of plutonium stocks is occurring outside the United States, almost wholly due to commercial reprocessing in France, Britain, Japan, Russia, and India. Stopping reprocessing in these countries is one of the more urgent non-proliferation tasks at hand; however, opening a repository in the US would do little to address the problem. It is inappropriate to pit short-term non-proliferation goals against the protection of future generations from gross environmental harm since it implies a discounting away the interests of people far into the future compared to those who are now alive.

It is noteworthy that those who stress non-proliferation over environmental concerns have not clearly addressed the serious non-proliferation dangers connected with the WIPP program. With the lion's share of resources for TRU waste management going to that repository, the problem of buried wastes is festering. The DOE has no comprehensive plans to remove these wastes, even though these near-surface dumps could become future mines for plutonium and possibly other weapons-usable materials after loss of site control, which is likely at some future time. For instance, there are estimated to be over 1,000 kilograms of plutonium-239 in the buried wastes at the Idaho National Engi-

SEE **SHORT TERM** ON PAGE 19

## SHORT TERM

FROM PAGE 18

neering and Environmental Laboratory alone — enough to make 200 or more nuclear bombs (see table below).

### Conclusion

So long as the politically expedient Yucca Mountain and WIPP programs command the lion's share of resources available for long-term management, no sound solution can be developed for nuclear waste. Hence, it is essential that the US government step back from these repository programs and initiate a much broader effort (see "Considering the Alternatives" article). In the meantime, it is essential that an interim management strategy be implemented that addresses the issues of safe storage, the legitimate complaints of nuclear utilities regarding the federal government's obligations, and the research and development that will be essential for a long-term program. The investment in Yucca Mountain and WIPP need not be thrown away. These facilities could be used for research on repositories using non-radioactive materials, pending approval by the state of New Mexico for WIPP, and by the state of Nevada and the Western Shoshone people in the case of Yucca Mountain.

1 I am grateful to Rochelle Becker, Beatrice Brailsford, Lee Dazey, Yuri Dublyansky, Kay Drey, Harold Fieveson, Steve Frishman, Charles Hollister, David Lochbaum, Michael Marriotte, Mary Olson, Auke Piersma, John Winchester, and Ian Zabarte for their reviews of a draft of this article and the article on long-term approaches. They may or may not be in agreement with the contents of these articles for which I, as the author, am solely responsible.

2 Transuranic waste is defined by the DOE as containing more than 100 nanocuries per gram of transuranic radionuclides that emit alpha radiation and that have half-lives of more than 20 years. The term transuranic refers to all elements that have atomic numbers greater than that of uranium.

3 See for instance, Arjun Makhijani and Scott Saleska, *High-Level Dollars, Low-Level Sense* (New York: Apex Press, 1992). See also *Science for Democratic Action* (SDA), Vol. 4 No. 4, Vol. 6 No. 1, and Vol. 7 No. 2, as well as IEER's report *Containing the Cold War Mess* (for WIPP-related issues). For details regarding one geologic aspect of Yucca Mountain see Yuri Dublyansky, *Fluid Inclusion Studies of Samples from the Exploratory Study Facility, Yucca Mountain, Nevada*, IEER, December 1998.

4 See IEER's report *Containing the Cold War Mess*, 1997 by Marc Fioravanti and Arjun Makhijani for a detailed analysis. Also see "Transuranic Waste: TRU and Consequences," *SDA* Vol. 7 No. 2, p. 7.

5 At a nuclear waste meeting sponsored by the DOE, a utility executive, in a frank expression of the NIMBY syndrome, told the DOE that it had to take the waste from the utilities and "I don't care where you put it." The ground rules of the meeting prohibit disclosure of the identity of the speaker but not what was said. A statement by Scott Peterson of the Nuclear Energy Institute in the *New York Times* provides another illustration: "The industry foremost is looking for movement of fuel," he is quoted as saying. ("Energy Agency Plans Offer to Take Utilities' Nuclear Wastes," *New York Times*, February 25, 1999.)

6 For more information about the use of transmutation as a waste management strategy, see "Transmutation not a Repository Alternative," *SDA* Vol. 6 No. 1, p. 4.

7 For a discussion of waste classification issues, see *High-level Dollars, Low-level Sense*, pp. 22–28 and Chapter 4. Also *SDA* Vol. 6, No. 1, pp. 8–13.

8 In some instances, such as in severe earthquake zones or on riverine islands, storage near the site may be safer than on site. However, moving the waste would give rise to its own issues and is generally difficult to accomplish.

9 Among the many options that have been proposed are: an MRS at Yucca Mountain; a "private" MRS such as the proposed site on the Skull Valley Goshute reservation in Utah; and storage at a DOE nuclear weapons site. The last is sometimes combined with suggestions that the spent fuel be reprocessed, for instance at the Savannah River Site.

10 Matthew L. Wald, "Plan to Bury Nuclear Waste in Nevada Moves Forward," *New York Times*, Dec. 19, 1998.

### PLUTONIUM IN BURIED WASTE AT SELECTED SITES

| Site | Amount of plutonium in buried waste, kilograms | Number of bombs equivalent[a] | Comments |
|---|---|---|---|
| Idaho National Engineering and Environmental Laboratory | 1,100[b] | 220 | The only site with an estimate that has a discoverable technical rationale |
| Los Alamos National Laboratory | Unknown | Unknown | Total quantity of plutonium-239 in all Los Alamos waste is possibly 610 or 1375 kilograms. Discrepancy is between two official estimates. |
| Savannah River Site | 250 (unreliable estimate)[c] | 50 | Does not include plutonium in high-level waste tanks estimated at 382 or 774.6 kilograms. Discrepancy is between two official sources. |

Sources: IEER's 1997 report *Containing the Cold War Mess*, Chapter 2. For discrepancies: Guimond, R.J. and E.H. Beckner, Memorandum on Plutonium in Waste Inventories, U.S. DOE, January 30, 1996.

a. We assume that 5 kilograms of plutonium are required for a nuclear bomb. Technologically sophistocated devices can be made with much less.

b. Plutonium-239 plus plotonium-240. Rounded to two significant figures.

c. Plutonium-239 only. Rounded to two significant figures.

## CONSIDERING

FROM PAGE 11

though this hypothesis would have to be carefully investigated before this method is selected. Upper mantle disposal would also address the thorny questions of deliberate or inadvertent human intrusion better than the other two approaches.

The safety, technological and scientific questions surrounding this option are as immense as its theoretical promise and it is unclear whether or not they can be resolved. For instance, the technology for drilling into the upper mantle does not exist and is not now under development. It is highly unlikely to be developed in the near future. However, drilling very deep boreholes may become more feasible with new technology such as cutting rocks with lasers.[12] It may also be possible to dispose of the waste in the stable areas of the upper mantle beneath the ocean floor, where the Earth's crust is less thick than under continental areas.

There are a host of safety issues surrounding upper mantle disposal. For example, even if sufficiently deep boreholes can be drilled, would they be stable enough to allow disposal of the waste all the way into the upper mantle? How would mishaps in lowering the waste be handled? How would the various layers of groundwater be sealed at great depths in order to permit waste emplacement?

Finally, the science around the estimation of the performance of upper mantle disposal is not developed. For example, drilling holes into the upper mantle may provide a path for magmatic flow to the surface, bringing radioactivity with it. The likelihood of such an event at a specific site would need to be assessed in the licensing process. Further, the upper mantle is presently inaccessible to direct measurement and investigation, so that its properties must be inferred in various ways. While these indirect techniques allow for an understanding of general structure and composition, it is not at all clear that sufficiently detailed knowledge can be developed to use this disposal technique with confidence. In the absence of new investigation techniques, the process of actually licensing this disposal method would be open to question.

In weighing the factors mentioned above, we have concluded that the theoretical potential of upper mantle disposal to keep long-lived radioactive waste out of the biosphere is high enough that it deserves significant financial resources, even though it appears unlikely at present that this approach would bear fruit.

### Conclusion

Selecting sites for land-based disposal of nuclear waste in geologic repositories is very premature. There has not yet been enough research to determine whether this approach is the best one. Moreover, even within the framework of geologic disposal, programs have been compromised by political expediency.

We have discussed three broad approaches to long-term waste storage that IEER believes should be studied in parallel: geologic disposal on land, sub-seabed disposal, and upper mantle disposal. The main aim of this research should be to yield sufficient data and analysis in one to two decades to enable a comparison between these options. If the first phase of the process reveals sufficient promise in sub-seabed disposal or upper mantle disposal, further work might be required before repositories can be ruled out, because problems with repositories are better known and those with the other two might take longer to emerge. At that time, one or two could be ruled out, if the data warrant, and further resources concentrated on the remaining approach(es). That would also be a more appropriate time to reconsider the question of whether and how a site selection process for disposal should be undertaken.

1 Hazardous chemicals may build up over time in containers with radioactive wastes due to the degradation of plastics and other materials by a process called radiolysis (see *Science for Democratic Action* vol. 7 no. 2, p. 21).

2 Kai Erikson, "Out of Sight, Out of our Minds," *New York Times Magazine*, March 6, 1994.

3 Michael Miklas et al., *Natural Resources Regulatory Requirements: Background and Consideration of Compliance Methodologies*, CNWRA

SEE **CONSIDERING** ON PAGE 22

## RECOMMENDATIONS

FROM BACK COVER

people in the case of Yucca Mountain. WIPP and Yucca Mountain would be permanently off the table as potential repositories because they are poor sites. Waste already put inside the WIPP repository should be removed from it. This will allow long-term research to proceed in an unfettered and complete fashion.

- Various kinds of repository types and environments should be studied for ten to fifteen years without any attempt to identify, rank, or screen specific locations as potential repository sites.
- Significant resources should be devoted to investigation of sub-seabed disposal, given that there are no ideal options for long-term waste management. These resources should not be used to add radioactive materials into the oceanic or sub-seabed environment.
- Upper mantle disposal (deep disposal beneath the biosphere) has enough merit as a concept that it deserves significant financial resources, even though the technology to implement this approach does not exist and the technical viability of this approach is questionable at the present time.

# Institutional Reform for Long-Term Nuclear Waste Management

In the nineteenth century, the British came up with the idea of a public corporation that was a semi-independent organ of government. A public corporation is owned by the government but has a clearly defined goal (or goals) specific to it. It functions independently of the government in its day-to-day operations. The Tennessee Valley Authority is an example of a publicly-owned corporation in the United States. A public corporation may make profits or it may be non-profit, depending on its charter. It may keep some of its profits for re-investment. Since the only "shareholder" is the government, any excess profits beyond investment (either for replacement of depreciated equipment or for growth) would be returned to the government.

IEER has recommended that a public corporation be established to handle long-term management of highly radioactive waste. A public corporation would have many advantages over the present set-up, whereby the Department of Energy (DOE), which has created and continues to create such wastes, is also responsible for site selection and repository development and operation. For a variety of reasons, the DOE has repeatedly failed in its environmental remediation program even when the technical concepts being implemented were along the right lines. Conflict of interest may be only a part of the reason. As an organization historically devoted to pursuing nuclear weapons and nuclear power that still has interests in these areas, the DOE appears unable to change its culture to one of environmental protection.

The idea of a private, profit-making waste management corporation funded by nuclear utilities suffers from serious shortcomings. Its attention to profit would be incompatible with the decades of research and development tasks that are needed before action on final disposal can be taken. A private corporation would lack the detailed accountability that can be built into a public corporation. Private companies can shield their records on the grounds that such information is proprietary, even if it is related to public health and the environment. For instance, cigarette companies kept secret much of their research on nicotine and other aspects of the health effects of smoking for decades on such grounds.

Creating a new government agency is also a poor solution. The vulnerability of the current system to short-term political pressures to the detriment of long-term research and development is a serious defect of the repository program. Setting up a new government agency does not address this problem because it would necessarily be subject to the vagaries of short-term political pressures and annual budgeting.

A federally chartered non-profit corporation appears to be an institutional framework that could have the strengths of both public and private sector approaches, if it is properly set up. It would operate under appropriate independent regulation, and the scrutiny of the public, the federal and state governments, and affected tribes. The corporation could tap into the nuclear waste management experience of the utilities as well as the innovative potential of the private sector by funding research and development (R&D) through a peer-reviewed, competitive process. Such processes are common in some existing governmental research programs. However, transparency and greater accountability to the general public in the grant-making process will be essential.

No institutional set-up can guarantee success or the integrity of the process. The corporation's technical and financial performance and accountability to the public will depend in large part on the methods and terms by which it is established. It is beyond the scope of this newsletter to suggest a detailed organizational structure, but some important criteria and institutional features can be outlined:

- The mandate of the corporation should be clearly specified. It should include the management of wastes on the sites of closed nuclear power plants and contracting and oversight of the R&D needed to understand and compare the different approaches to long-term management. Research would be done at universities, by private non-profit groups, as well as by industry, with proposals being screened by publicly-determined criteria. The corporation could also conduct some of the R&D itself.
- On-site storage by the corporation should be regulated by the Nuclear Regulatory Commission, as well as state environmental agencies.
- The composition of the board of directors of the corporation should ensure that the interests of states, Native American tribes, and communities affected by nuclear power plants are properly represented.
- The conduct of the corporation's business should be transparent in its financial, scientific, and other aspects, to allow effective public and congressional scrutiny throughout the process. As a general rule, the documents of the corporation would be public.
- The scientific and technological results of the publicly-funded R&D program should be publicly owned — that is, patent and other property rights

SEE **INSTITUTIONAL REFORM** ON PAGE 22

## INSTITUTIONAL REFORM

FROM PAGE 21

should belong to the public and not to any private entities that contract to do the work.

- The Nuclear Waste Fund should be allocated to the work of the corporation, which would be strictly accountable financially, and in the accomplishment of scientific and technical goals and schedules (with due regard for the uncertainties inherent in scientific accomplishments of the type under consideration). The Fund will need to be walled off from other parts of the federal budget in order to protect the waste management corporation's operations from short-term political pressures. If the R&D over the next few decades is along the lines we have suggested (see article on short- and medium-term management, page 1), the Nuclear Waste Fund may be sufficient to cover it as well as on-site storage, but not long-term disposal. The Nuclear Waste Fund would likely need to be augmented through a higher fee on nuclear utilities to recover long-term disposal costs. This recovery should not be delayed since it will be difficult or impossible to collect fees after nuclear power plants are shut, when the disposal would actually be implemented. A higher utility contribution to the Nuclear Waste Fund with the monies being placed in interest-bearing escrow may be one solution. If the money is not needed, it would be returned to ratepayers or their designees.

## CONSIDERING

FROM PAGE 20

92-022 (San Antonio, Texas: Center for Nuclear Waste Regulatory Analysis, 1992), p. 3–37.

4 Waste Isolation Systems Panel of the National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Waste*. (Washington, DC: National Academy Press, 1983).

5 Free-fall seabed penetrators can currently successfully embed research instruments 60 meters or so in sediments beneath sea floor, in water depths of over 5,000 meters. The work has been conducted by the European Joint Research Centre in collaboration with others using penetrators made in Ispra (Italy). See http://www.tinet.ch/odm01/ffp-01.html.

6 Milnes, op cit. and Charles Hollister, D. Richard Anderson, and G. Roth Heath, "Subseabed Disposal Of Nuclear Waste," *Science*, Vol. 213, No. 4514, Sept. 18, 1981.

7 At some locations, such as Yucca Mountain, there may be a risk of high individual exposures due to radioactivity being spewed out by volcanic eruptions. A repository at Yucca Mountain above the water table may also result in the release of carbon-14 in the form of carbon dioxide. This would produce tiny individual doses. But since the half-life of carbon-14 is long and since it gets into plant life, global population doses over thousands of years could be very high. Applying risk coefficients currently used by the EPA, the estimated cancer fatalities from a Yucca Mountain repository could run into thousands, globally over a long period just from the carbon-14 exposure. There is considerable controversy over whether such calculations for very small individual doses over-predict or under-predict health damage. See EPA, *Review of the Release of Carbon-14 in Gaseous Form from High-Level Waste Disposal*, EPA-SAB-RAC-COM-93-010, April 29, 1993. The potential of hydrothermal events to carry radionuclides to the surface also needs to be addressed for the Yucca Mountain site. See Yuri Dublyansky, *Fluid Inclusion Studies of Samples from the Exploratory Study Facility, Yucca Mountain, Nevada*, IEER, December 1998. It should be noted that even though the EPA only considered cancer risk, carbon is the basic element in living matter, including DNA. Therefore, the genetic and immunological effects of carbon-14 as well as its effects on developing fetuses need to be carefully considered.

8 Robert R. Hessler and Peter A. Jumars, "Abyssal Communities and Radioactive Waste Disposal," *Oceanus*, Vol. 20, No. 1, Winter 1977, p. 44.

9 Some use of US naval submarines and other vessels for environmental investigations is already occurring.

10 Sybil Parker, Editor-in-Chief, *McGraw Hill Encyclopedia of the Geological Sciences*. New York: McGraw-Hill, 1987, pp. 140–147 and 396–399.

11 Disposal in deep boreholes within the Earth's crust has been discussed as a possibility both for plutonium (NAS 1994, op cit.) and for high-level waste. For a summary of the latter see A.G. Milnes, *Geology and Radwaste*. New York: Academic Press, 1985. This book contains a survey of various methods of high-level waste disposal and also a good overview of basic geology important for understanding radioactive waste disposal.

12 Josh Chamot, "Cold War's Hot Technology," *Geotimes*, Sept 1998, pp. 10–11.

## ERRATA/UPDATES

**1.** The last issue's Dear Arjun column (p. 21) contained a confusing sentence that we would like to clarify. In a discussion on chemical breakdown caused by radiolysis, we wrote that:

*They [chemical reactions resulting from radiolysis] also frequently result in the generation of hydrogen gas due to the radiolysis of water and of organic compounds, as well as of other toxic and flammable compounds.*

A better way of stating that would have been:

*Radiolysis of waste and organic compounds frequently results in the generation of hydrogen gas, as well as of other toxic and flammable compounds.*

**2.** In Science for Democratic Action Vol. 6 No. 4-Vol. 7 No. 1 we printed a table (p. 20) with figures on military and commercial plutonium stocks. Because many countries do not release this information publicly, all numbers are estimates.

Since the publication of that issue, we have become aware of additional information about two countries that we want to pass on to our readers.

In July 1998, Britain released figures on its military stocks of fissile materials as a part of a policy to "be as open as possible about nuclear issues..." announced in its Strategic Defence Review. These were: 7.6 metric tons of plutonium and 21.9 tons of highly-enriched uranium. Note that these are more than double the figures that we had printed.

We have also come to learn that our estimates of German separated commercial plutonium were much too low. A better estimate is about 25 metric tons.

(INESAP Information Bulletin, No. 16, November 1998; Plutonium Investigation No. 4-5, WISE-Paris, March-April 1998.)

# It pays to increase your jargon power with Dr. Egghead

### Upper mantle disposal

1. What happens to the knick-knacks you give to your grandparents.
2. A common practice among medieval kings of stuffing dinner leftovers into the hoods of their cloaks.
3. What to do when the top of your camping stove gets stepped on by a bear.
4. A theoretical long-term waste management method in which waste containers would be lowered into extremely deep boreholes extending below the Earth's crust. This method's potential for removing waste from the biosphere makes it an attractive area for research. The technology necessary for upper mantle disposal does not currently exist, and is unlikely to be developed in the near future.

### Monitored Retrievable Storage

1. Daycare.
2. The back corner of your refrigerator.
3. A safety deposit box.
4. An interim, centralized, above-ground storage facility where spent fuel would be sent until a long-term management option has been developed and licensed. Sites suggested in the US have included Yucca Mountain, a "private" facility on the Skull Valley Goshute reservation in Utah, and storage at a Department of Energy nuclear weapons site (see p. 17–18).

### Engineered barrier

1. High-tech roadblocks recently installed around the White House.
2. An infamous comprehensive exam administered to second-year technical students to keep down the numbers of graduating specialists.
3. Difficulties experienced by female railway employees in advancing their careers.
4. Human-made containment structures to complement or supplement geologic containment of radioactive wastes in a repository. These include waste containers and special backfill materials. Ideally, these barriers should be patterned after natural materials and structures that have contained radioactivity for millions of years.

### Rock melting

1. A hot new video game, sequel to "asteroid obliteration."
2. A form of 1990s social protest, in which teenagers burn their parents' old vinyl records.
3. The tendency for chart-topping bands to split up.
4. A discarded idea for waste disposal, in which high-level waste would be injected into a mined area deep underground. Theoretically, the heat from the waste would melt the surrounding rock and the resulting rock-waste would cool and solidify, immobilizing the waste.

### Pangea

1. A new Cristo project to wrap a piece of pink plastic around the earth.
2. Any organization dedicated to worshipping half-goat demi-gods.
3. The stuff at the bottom of the pan when you forget to turn off the burner.
4. The name of a private, multinational corporation which is seeking to develop an international repository in Australia, to which high-level waste would be shipped from other countries.

## Atomic Puzzler

The Atomic Puzzler is on vacation as Gamma is off to New Mexico. Dr. Egghead's trusty sidekick has been called back into duty as a Citizen Inspector after the opening of WIPP. Gamma will be inspecting the site to search for hazardous waste that may have been placed there before the granting of an appropriate permit (see Atomic Puzzler in the last SDA). We hope to see the waste that has been placed at WIPP removed, and to have Gamma and the Atomic Puzzler back for next issue.

## RECOMMENDATIONS FOR HIGHLY RADIOACTIVE WASTE MANAGEMENT

**Policy/regulatory structure**

- Waste should be reclassified to reflect longevity and hazard.
- Wastes that threaten to exacerbate environmental contamination in the short- and medium-term, such as buried TRU waste and liquid high level waste should be stabilized and retrievably stored, pending long-term disposal.
- Irradiated reactor fuel (also called spent fuel), TRU waste, and military high-level waste should be stored as safely as possible on site or as close to the point of generation as possible for an interim period (several decades) that would be long enough to allow a long-term management plan to be implemented.
- The federal government should pay for additional on-site storage necessitated by delays in the repository program but only for wastes covered by existing license periods for presently operating reactors. The funds should come from the Nuclear Waste Fund and not from general taxpayer revenues.
- A firm commitment should be made against reprocessing of spent fuel.
- Currently the United States does not have an adequate program or institutional framework to handle long-term management of highly radioactive waste. We believe the best approach to solving this problem is a federally chartered non-profit corporation which would develop and implement a long-term waste management program, and would take ownership of spent fuel after reactors are shut under existing reactor licensing lifetimes. Most or all of the necessary R&D work would be contracted out to universities, non-profits, and industry on a competitive basis. The Nuclear Waste Fund would be used to finance the operation of the corporation. The rate payment into the Waste Fund by nuclear utilities should be such that it will cover all the costs of the program.
- Spent fuel from existing nuclear power plants beyond their presently licensed lifetimes or from new nuclear power plants should be excluded by law from federal assumption of waste management liabilities. Liability for waste generation attributable to future production of nuclear weapons or weapons-usable materials should be borne by the Pentagon or the Defense programs part of the Department of Energy.

**Research and development**

- Research should be conducted into development of engineered barriers that mimic natural materials and structures that retard the migration of radioactivity for millions of years or more.
- It is clear that before any method is chosen for permanent disposal of radioactive waste, additional research on disposal techniques is required. A great deal of work has already been done at WIPP and Yucca Mountain and these sites should be converted into research centers for research on geologic disposal, engineered barriers, testing of materials for engineered barriers, etc. using only non-radioactive analog materials. This conversion should be subject to approval by the state of New Mexico for WIPP, and by the state of Nevada and the Western Shoshone

SEE **RECOMMENDATIONS** ON PAGE 20

**The Institute for Energy and Environmental Research**
6935 Laurel Avenue, Suite 204
Takoma Park, MD 20912

Address correction requested.





IEER PRESS