# Complex Cleanup

Cleaning up the legacy of decades of nuclear weapons production offers a prodigious challenge. The U.S. Department of Energy (DOE), which is responsible for cleanup in the United States, readily acknowledges the Herculean nature of the task. "We have large amounts of radioactive materials that will be hazardous for thousands of years; we lack effective technologies and solutions for resolving many of these environmental and safety problems. We do not fully understand the potential health effects of prolonged exposure to materials that are both radioactive and chemically toxic," says a 1995 DOE report, *The Challenge before Us.*

The figures are staggering: cleanup will involve over 2.3 million acres of land, sites in at least 24 states, a time line extending well into the next century, and costs of over $200 billion, according to the 1995 report. In addition, the DOE must ensure the health and safety not only of those performing the cleanup, but also of the people whose homes and businesses surround the contaminated sites. The DOE must also comply with complex state and federal laws regulating how these sites must be remediated, including the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act, better known as Superfund.

The DOE's management of the task so far has received a mixed review from at least one watchdog group. The Institute for Energy and Environmental Research (IEER), a public interest organization in Takoma Park, Maryland, concluded in an October 1997 report, *Containing the Cold War Mess,* that the DOE has made considerable progress in describing the nature of the environmental remediation and waste management problems that must be solved, but is pushing ahead with "the most expensive environmental program in history" without standards to guide it.

The IEER report was updated in March 1998. While praising the DOE for being more open about "past misdeeds," the IEER held to its initial conclusions. The DOE disputes those conclusions, arguing that it complies with numerous environmental regulations and is following and evolving sound management practices to protect the environment and the health of the public and the workers involved in the cleanup.

### The Nature of the Wastes

The nuclear wastes of most concern located at the former weapons sites are transuranic (TRU) wastes and high-level wastes. TRU elements are man-made and are atomically heavier than uranium. These elements emit alpha particles—radiation in the form of two protons and two neutrons. The chief danger of alpha radiation lies in exposure by inhalation; when alpha radiation is absorbed by the lungs, it can lead to cancer. TRU elements are a source of concern largely because of their sometimes very long half-lives (the time it takes for a unit of the element to lose half its radioactivity). Perhaps the most worrisome TRU element is plutonium, with a half-life of 24,000 years.

High-level waste is radioactive material resulting from the reprocessing of spent nuclear fuel. This waste includes elements such as cesium 137 and strontium 90. Low-level wastes, which are of less concern, are essentially defined by exclusion as being neither high level nor transuranic.

But many DOE sites contain other potentially hazardous materials besides radioactive wastes. For instance, at the Savannah River Site in Aiken, South Carolina, there are ponds contaminated by mercury, a known neurotoxin. Ironically, the mercury wasn't generated by any process at the site. Rather, it came from the Savannah River itself, when its water was used to cool nuclear reactors on the site. Also at the 300-square-mile site are patches of soil contaminated with cadmium, lead, chloroform, and other dangerous chemicals. Other potential contaminants include solvents such as carbon tetrachloride (a carcinogen) and beryllium (a metal used to make weapons that can cause severe, chronic lung damage).

While the DOE acknowledges that soil and water have been contaminated by TRU wastes, it maintains in its response to the IEER report that "neither stored nor buried TRU waste pose a near-term risk to human health and the environment." Mark Fioravanti, a project engineer with the IEER and one of the report's coauthors, says, "We take pretty serious issue with that [statement]. We think there's significant evidence of mobility in the environment of the buried transuranic wastes." Both liquid and solid waste, he says, have migrated through soils. But James Werner, director of strategic planning and analysis in the DOE's Office of Environmental Management, says, "If you have material moving, you just have to make sure no one's drinking the groundwater. And having done that, we can say there is no near-term risk to public health and the environment." Still, he says, making sure that wastes don't become part of the water supply is only part of the solution, and the potential long-term risks need to be examined carefully.

The risk of explosions at nuclear waste sites is also a concern. Such an explosion occurred in Mayak in the former Soviet Union in 1957. According to the DOE, the explosion of a tank of high-level waste radioactively contaminated 9,000 square miles. The 10,000 people in the area each received an average radiation dose of approximately 50 rem, or 10 times the current annual limit for U.S. nuclear industry workers. Seventy-five square miles of the region remain uninhabitable today.

According to the IEER report, heat resulting from high concentrations of radioactivity contributed to that explosion. Similar high heat levels have been reported in some tanks of high-level radioactive waste at the Hanford Site in eastern Washington State, each which can contain over 200,000 gallons of radioactive material. Approximately 3 million people live in the 75,000 square miles surrounding the Hanford Site, according to the Agency for Toxic Substances and Disease Registry (ATSDR).

Frank Parker, former chairman of the National Research Council's board on radioactive waste management, downplays the similarity between the Hanford tanks and the ones at Mayak. "In theory, they have similar components," he says, "but there are dissimilarities." According to Parker, the temperatures are different at the two sites, there's a lot more water (coolant) at the Hanford Site, and there are more careful controls there as well. Says Parker, "It's hard to conceive that an explosion could occur [at Hanford]."

### Concern about Workers

One of the major aspects of the cleanup is ensuring the health and safety of those who do the actual work of cleaning up. As part of a program to understand and control worker exposure to radiation and toxic chemicals, the National Institute for Occupational Safety and Health (NIOSH) is conducting a study of the conditions to which cleanup workers would be exposed and will provide recommendations to the DOE for the department's worker health surveillance programs. Steven Ahrenholz, a research industrial hygienist at NIOSH and a member of the monitoring team, says workers are likely going to have to remove radioactive material that has been left in equipment or that has been sealed off in buildings. Sealing off radioactive materials, says Ahrenholz, works to keep people safe "until you have to tear the building apart."

Solvents and other chemicals present at hazardous waste sites also present risks, Ahrenholz says. "We're talking about tank cars full of stuff. . . . In some instances the materials have been disposed of on site. There may be materials [that workers] are going to have to clean up that are in the soil," he says. Records and data on chemicals used at the sites may simply not be available, creating significant unknowns that have to be dealt with. The technologies and processes used to clean up the sites need to be understood as well, Ahrenholz says. Disassembling radioactive structures and putting them in safe storage has been limited in the past, he notes; the process will also involve new technologies. The question arises whether that process, once developed, will present potential occupational exposures to toxic chemicals to the workers.

DOE officials assert that the department is aware of the risks and is working to mitigate them. The NIEHS provides funds for programs to train workers to deal safely with cleanup tasks confronting them at nuclear weapons complexes through the Superfund Worker Training Grant Program. The programs are administered through labor unions and universities. According to Alex Ruttenberg, associate director of the National Clearinghouse for Worker Safety and Health Training, there have been over 1 million contact hours in courses designed to teach workers how to appropriately handle the hazards, such as radiation and asbestos, that cleanup jobs present.

A 1995 independent evaluation of the NIEHS grant program noted that "there is a wealth of descriptive information available from workers and clients to indicate substantial reductions in serious injuries" The report added that NIEHS-trained workers promote a safety-conscious climate. Ruttenberg says the DOE now shows much greater concern about health and safety than it did in the past. "If you look at where the [weapons] complex was five years ago and where it is now, from a health and safety perspective, it's night and day," he says.

The evaluation report noted, however, that there are no extensive surveillance data to measure the NIEHS program's success. While the ultimate measure of such training is the reduction of work-related injuries and illness, the report states that "this kind of systematic data is not available for reasons endemic to the whole field of occupational safety and surveillance." Such reasons include the infeasibility of gathering such data, according to John Dement, an associate professor of epidemiology and industrial hygiene at Duke University Medical Center in Durham, North Carolina, who chaired the evaluation panel. The problem, Dement says, is that illnesses such as cancer are not reportable to health agencies such as the Centers for Disease Control and Prevention (CDC). And, he says, there are no baseline data against which to compare accident and injury rates. Workers' compensation data are poor and the workers themselves are fairly nomadic; they work for a few days or weeks at one site before moving on, which makes tracking them difficult. NIOSH is collecting background data on potential exposures and trying to identify cleanup workers. That, Ahrenholz says, may not be easy with multiple contractors and subcontractors doing the work. "Identifying who the workforce is is becoming increasingly complex, because you don't have one employer," he says. Being able to track the workforce is important in determining potential links between health effects and exposure to industrial chemicals and radiation.

Tara O'Toole, assistant secretary for environment, safety, and health at the DOE from 1993 to 1997, says the department

became committed to emphasizing worker safety with a program called Integrated Safety Management. This program was recommended in 1995 by the Defense Nuclear Facilities Safety Board (DNFSB), an independent agency created by Congress in 1989 to oversee the DOE's cleanup efforts. The program means getting both workers and managers to work cooperatively and not take foolish chances, O'Toole says. For example, instead of tearing out asbestos (which can cause cancer when inhaled), a better option may be to seal it in place. That saves money and time and probably reduces health risk, she says.

The demands of the cleanup process are changing the DOE's thinking about worker safety, notes Peter Brush, the department's principal deputy assistant secretary for environment, safety, and health. Brush says that in the past, the DOE wasn't used to dealing with worker safety issues arising from demolition and exposure to chemicals and other hazardous materials. Brush anticipates that cleanup will lead to "real reductions in the kinds of occupational safety problems that the DOE has historically suffered," he says. But he also acknowledges that putting such a program into practice may not be easy. "Some DOE facilities would rather follow the old command and control operation, where workers were not given the right to participate in work planning and hazard analysis," he says.

The DNFSB's 1998 annual report to Congress notes that during the past several years a "poor definition of the responsibilities and authorities of DOE staff members has been a weakness affecting DOE's ability to manage its safety responsibilities." The report also states, however, that the department's efforts in response to a number of technical recommendations have improved safety "despite increased hazards associated with the stabilization of highly radioactive substances remaining from previous operations and the decommissioning and decontamination of highly contaminated facilities."

Among the recommendations the board made is the requirement that conforming Integrated Safety Management practices be part of the contract between the DOE and the contractors who operate nuclear weapons facilities for the department. The DOE, following the board's recommendations, has also clarified and better defined the safety responsibilities of site managers.

## Health in the DOE's Neighborhood

The impact of hazardous waste sites on those who live around them is another matter under scrutiny. The health of these people is being monitored by the ATSDR, which has analyzed about half of the 26 DOE sites classified as Superfund sites. Using environmental monitoring data from the DOE, the EPA, and state health departments, data on disease rates around the facilities, and information from local residents concerning their health, the agency has found reason to be concerned at the Hanford Site, according to Joseph Hughart, deputy director of the office of federal programs at the ATSDR.

Radioactive iodine was released into the air in the area around the Hanford Site in the late 1940s and early 1950s. The iodine fell onto the grass that was eaten by dairy cattle. "Children who drank milk [from local cattle] received fairly high doses [10 rads] of radioactive iodine," says Hughart. Because doses that high (approximately 40 times higher than a dental X-ray dose) have caused thyroid cancer and other thyroid problems in humans, the ATSDR has set up a program to monitor the health of area residents for thyroid illnesses. The CDC has also begun a study to assess the incidence of thyroid illnesses in the area.

Also at Hanford, groundwater contaminated with radioactive strontium 90, cesium 137, tritium, and technetium 99 from the site is moving toward the Columbia River. Hughart says the ATSDR is particularly concerned about whether salmon in the river will absorb these radioactive elements, thus increasing the cancer rate among the American Indians who eat the fish. But Woody Cunningham, technical director of the DNFSB, notes that it will be about 20 years before that radioactivity can reach the river. By that time, he says, much of the radioactivity will have naturally decayed. But, he concedes, there are small quantities of longer-lived radioactive elements present at the site, such as spent nuclear fuel from nuclear reactors that is housed in badly deteriorating buildings. The DOE has agreed to a DNFSB recommendation to move the fuel into a more secure facility but, according to Cunningham, the department has "gone through a series of contractor changes, and the schedule has been delayed on the order of 19 months compared to the original schedule DOE promised."

Meanwhile, from the Idaho National Engineering and Environmental Laboratory, DOE researchers report in the 15 December 1998 issue of *Environmental Science & Technology* the amounts of three long-lived TRU elements—technetium 99, neptunium 237, and uranium 236—that were discharged to the groundwater by injection wells. The half-lives of these elements are approximately 300,000 years, 2 million years, and 20 million years, respectively. According to the report, however, the amount of these wastes in the water is far below the EPA's drinking water standards. The highest level is that of technetium 99, which is only 1.4% of the drinking water standard. The concentration of the other elements is far below 1.0% of the standard.

In Ohio, radioactive emissions from the former Feed Materials Production Center in Fernald, Ohio, which operated from 1951 to 1988 converting uranium into metal for nuclear weapons, are blamed for a 1–12% past and future increase in lung cancer deaths in the surrounding area. This was the finding of an 18 March 1998 draft report of a CDC study entitled *Estimation of the Impact of the Former Feed Materials Production Center (FMPC) on Lung Cancer Mortality in the Surrounding Community.* According to the report, these percentages translate into an estimated 25–309 deaths. The period covered by the estimate ranges from 1951 to 2088. Decay products released into the air and into ground wells from uranium processing and storage are blamed for the illnesses. The report adds that future studies will examine kidney and bone cancers, illnesses that are perceived by the community to be related to past releases of radioactive materials from the site. Biological and other scientific evidence indicate this perception may be correct.

At some DOE locations, contamination does not threaten the general population because the sites are so large that contamination simply doesn't get off site. The problems occur where a site is close to a community or where the toxic or radioactive emissions are very high.

## Waste Disposal

Cleaning up the waste often means moving it. TRU waste, in general, is destined for the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico [see *EHP* 102(10):832–835(1994)]. The plant is actually a deep burial vault, where waste in specially designed, 55-gallon carbon steel drums will be placed in rooms carved out of sodium chloride rock, located 2,150 feet below the surface. Scheduled to open in early 1999, the $19 billion facility is designed to store 850,000 drums of TRU wastes. EPA standards require the facility to be built so there will be an increase of no more than 1,000 cancer deaths over the next 10,000 years due to exposure to radiation from the project. That works out to 0.1 cancer deaths per year, says Robert Neill, a health physicist and director of the New Mexico Energy and Environment Group, a federally funded, independent agency set up to monitor the facility. Radiation at the site

boundary can be no greater than 25 millirem per year, according to the DOE. The background level of radiation to which the U.S. population is exposed ranges from 0.25 to 0.4 rem annually.

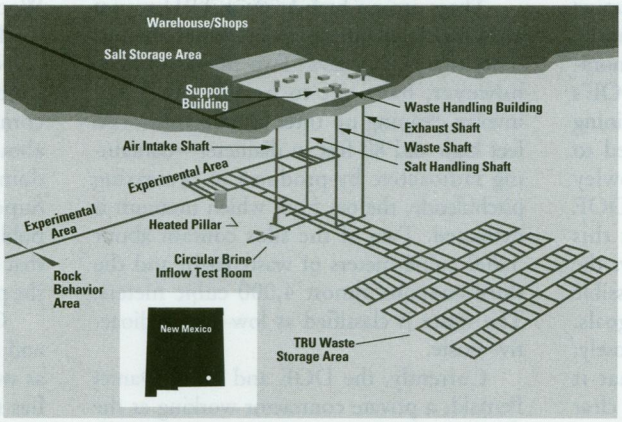
Whether WIPP will open on schedule is uncertain, however. The Southwest Research and Information Center in Albuquerque plans to sue to block the opening of the mine, says Don Hancock, director of the center's nuclear waste safety project. He says the presence of brine under pressure below the plant poses a safety threat, and argues that it might break into the burial vaults and carry radioactive waste to the surface. There are other safety concerns though, according to Neill. The lids on the storage drums are designed to stay on in the event of a 4-foot drop, but the drums will be raised 10 feet above the floor as they are being put into WIPP, he told the New Mexico Radioactive Consultation Task Force at a 13 April 1998 meeting. Should one of the drums be dropped from a height of greater than 4 feet, it is unclear whether wastes might be spilled.

These concerns are unfounded, according to DOE spokesman Dennis Hurtt, who says a number of safety precautions have been taken to ensure the safe transport and storage of the materials once they reach the site. The waste will be trucked to WIPP in transuranic package transporters—containers measuring 10 feet high and 6 feet in diameter, consisting of an inner cylinder surrounded by 10 inches of polyurethane foam and a half-inch of ceramic fiber for insulation, covered by a stainless steel shell. According to the DOE, these transporters have successfully passed drop and puncture tests including being dropped 30 feet onto a 25-foot-thick concrete surface covered with an 8-inch steel plate.

According to the DOE, the shipments will be monitored by satellite tracking from WIPP. The trucks will also be fitted with communication equipment and radiation monitors. Shipments will be made over interstate highways and will be suspended during threatening weather. Routes will skirt urban areas where possible. Medical and emergency responders along the route will be notified when shipments are being made.

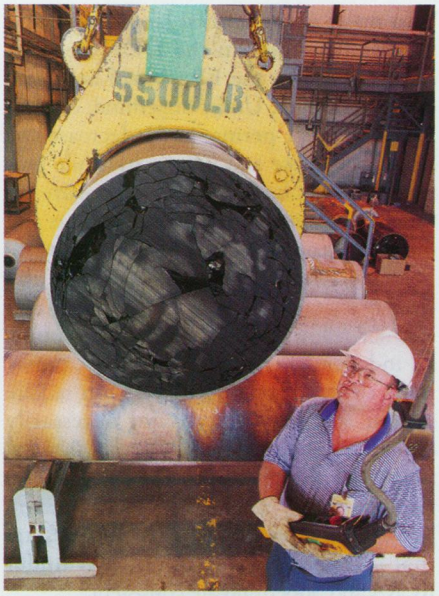
High-level waste that has been vitrified, or turned into glass, is to be stored in a DOE repository in Yucca Mountain in Nevada, scheduled to open in 2010. (Although Yucca Mountain has not been officially designated as a storage area, it is the only site being explored for storage of high-level waste.) In simplest terms, vitrification involves adding sand to the waste mixture, heating it in a smelter or furnace, and cooling the resultant liquid into glass, thus trapping the contaminant inside. The DOE is proud of its two vitrification efforts, one at a DOE facility in West Valley, New York, and one at the Savannah River Site. "We've already vitrified over 200 canisters. We've got two of the largest vitrification facilities in the world now operating," says Werner. But he cautions that some of the waste to be vitrified in the future will require different technologies to address problems such as dealing with flammable material present in the waste.

Another problem is transportation of the waste to the Yucca Mountain site. The DOE has not yet decided whether the waste will be transported by truck or by rail, but rail seems most likely as larger amounts can be moved at a time. The casks that will contain the waste have not yet been designed, says James Carlson, director for waste acceptance and transportation in the DOE Office of Civilian Radioactive Waste Management, but they will be required to meet conditions imposed by the Nuclear Regulatory Commission. According to Carlson, the DOE will notify states and American Indian reservations along the transport route when shipments will be made, and will provide funds for training officials to respond in the event of an accident.




DOE

**Saline solution.** The thick salt beds underlying the WIPP in Carlsbad, New Mexico, provide a geologically stable berth for transuranic wastes and act as a concrete-like radiation shield.




DOE

**Hazardous waste *in vitro*?** In the vitrification process, high-level waste is mixed with sand, heated to melting, and cooled in canisters, thereby trapping contaminants in glass blocks.

## A Tale of Two Sites

***The Savannah River Site.*** The Defense Waste Processing Facility, which vitrifies waste at the Savannah River Site, opened in March 1996. The waste to be vitrified is stored in underground million-gallon-capacity tanks. The waste is present at the site in two forms—a crystal solid and a sludge. The solid, which contains primarily cesium 137, is stored in 22 tanks. The sludge, a mixture of heavy metals and strontium 90, is stored in 23 tanks. Only the sludge at the Savannah River Site is being vitrified.

The vitrification process is run by remote control because of the dangers of worker exposure to radioactivity. The vitrified waste goes into metal casks measuring 10 feet high by 2 feet in diameter. The casks are stored on site, with shipment to Yucca Mountain scheduled for 2015, says Roy Schepens, deputy assistant manager for high-level waste. Since vitrification began, two of the tanks have been emptied of sludge.

But Kevin Crowley, director of the National Research Council's Board on Radioactive Waste, complains that the vitrification plant, which costs $150 million per year to run, took too long (13 years) to build and was over budget, at a cost of $2.5 billion in construction and start-up expenses. Crowley's complaint echoes that of many who think the current programs to dispose of hazardous waste simply cost too much.

One attempt at the Savannah River Site to ready the solid form of high-level waste for vitrification was a half-billion-dollar failure. The In-Tank Precipitation Project, designed to concentrate high-level wastes, was abandoned in January 1998 after over 10 years of effort to make it work. The process generated high levels of benzene gas, an inflammable carcinogen. Schepens concedes that more testing should have been done on the process, but says the approach was weighed against other alternatives and chosen because it was a low-cost option.

However, Brian Costner, executive director of the Energy Research Foundation, a South Carolina citizens' group that monitors the Savannah River Site, says the DOE's selection of this process excluded examining alternatives and that the agency failed to conduct adequate pilot testing. Crowley shares Costner's view, and says the DOE ignored warnings from experts that this method would not work. Schepens says the DOE is now evaluating over 100 possible methods to accomplish its cleanup goals. This time, the DNFSB is watching closely; the board's 1998 report asserts that it "intends to ensure the DOE defines a clear path forward to resolving the technical questions that remain . . . and that the DOE consider what will be done if these issues cannot be resolved satisfactorily."

TRU wastes are also a factor at the Savannah River Site. TRU wastes generated before the early 1970s are buried on site under an impermeable soil cap that protects them from rainwater, which could wash them into streams, says Thomas Heenan, assistant manager for environmental quality at the site. The 76-acre cap is an interim measure while the DOE decides on the best treatment for the waste. Options include leaving the wastes in the ground or storing some of them safely above ground.

Leaving the buried wastes where they are, at least for the next few years, is best, argues Heenan. Digging them up could expose workers to radiation and industrial accidents, he says. "Right now, every indication is the buried waste is stable and it's not showing up in the drinking water," he adds, disagreeing with the IEER's contention that buried TRU wastes pose a threat to human health and the environment because they can move into groundwater. Other TRU wastes are in barrels or other containers, and are being readied for shipment to WIPP. Much of the waste is contaminated equipment or paper.

***Fernald.*** Meanwhile, at the 1,050-acre Fernald site in Ohio, efforts are moving ahead to dismantle the buildings and equipment designed to supply uranium metal for nuclear weapons. Unlike the Savannah River Site, which will continue to play a role in nuclear processing, the Fernald site is being completely razed. Cleanup is thus farther advanced than at other sites, says Graham Mitchell, head of Ohio's Office of Federal Facilities Oversight. Three of 10 major buildings on the site have already been demolished, says Jack Craig, director of the DOE's Fernald Environmental Management Project. Craig says 700,000 cubic feet of waste is being readied for shipment to commercial disposal facilities. That part of the project alone will take eight years, he says.

There are no high-level or TRU wastes at Fernald, making disposal easier than at other sites, Craig says. Two major projects, however, have yet to be started. They involve cleaning up three massive silos—36 feet high and 80 feet in diameter—containing radioactive by-products of processing pitchblende, the ore from which uranium is extracted. Two of the silos contain about 3,000 cubic meters of waste each, and the third contains almost 4,000 cubic meters. The waste is classified as low-level radioactive waste.

Currently, the DOE and Fluor Daniel Fernald, a private contractor working at the site, are in the process of soliciting proposals from companies for ways to safely and efficiently dispose of the waste. Processing that waste worries Lisa Crawford, president of Fernald Residents for Environmental Safety and Health, a local citizens' group. She is concerned that removing waste from the silos may spread radioactive pollution into the air. Right now, the waste is sealed by thick caps of artificial soil. Craig asserts that the waste removal processes will be closely monitored to prevent health risks. If radioactivity exceeds safe levels, he says, work will be stopped or other measures will be taken to ensure safety.

The Fernald work is scheduled to be finished by 2008. Because some of the waste will remain buried on site, the site's future uses will not include agricultural or residential purposes, according to the Ohio EPA and the Fernald Residents group, but it may be turned into green space.

## Legal Matters

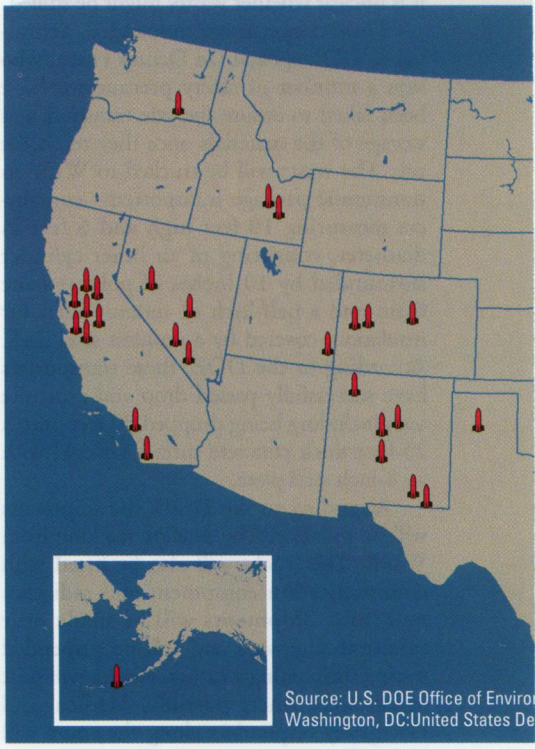
Two major environmental laws—Superfund and RCRA—govern the DOE cleanup. Superfund gives the EPA broad authority over site cleanup. Under Superfund, cleanup methods must permanently decrease the amount of waste and its toxicity while protecting human health. RCRA has a narrower focus and governs the treatment, storage, and disposal of nonradioactive hazardous wastes.

Superfund and RCRA have differing cleanup standards, according to Kate Probst, a senior fellow at Resources for the Future, an independent Washington, DC, policy study center. Though both laws can require similar actions, they are not necessarily duplicative, she says. The DOE can, she says, simply talk to regulators and arrange to perform one action instead of two that appear to be required under the laws. The EPA ensures that standards and requirements under RCRA and Superfund are consistent.

James Woolford, head of the EPA's Federal Facilities Restoration and Reuse Office, says that both Superfund and RCRA take worker safety into account. But, Woolford says, when it comes to protecting workers, the EPA defers to the DNFSB. "DNFSB sets out orders that entail worker safety within the [DOE nuclear weapons] complex," he says. "They are very strict about worker safety." When the DOE is doing a cleanup at a site under RCRA or Superfund, the agency cannot jeopardize public safety. Among EPA requirements are that signs be posted around the site notifying the public that a site is being cleaned up.

Cleanup agreements under both RCRA and Superfund involve the site's home state as well as the DOE and the EPA. The state has the option to become involved. "As a matter of policy, EPA will approach the state and try to solicit their involvement," Woolford says. "Hopefully, they will become a party to our cleanup agreement." The EPA has delegated its RCRA authority to states in most cases, allowing them to issue cleanup permits and impose technical standards and record keeping requirements.

When a Superfund cleanup is underway, says Woolford, an agreement between the EPA and the DOE sets out cleanup deadlines. Woolford says, though, that the



Source: U.S. DOE Office of Enviro
Washington, DC:United States De

agreement deadlines can be affected by congressional action. For instance, if Congress fails to appropriate the amount of money the agency requests for cleanup, the deadlines can be altered.

## Summing Up

Critics and observers of the DOE acknowledge that the department has made marked

## Office of Environmental Management Sites Awaiting Cleanup Completion

| Site | Location | Date of Completion |
|---|---|---|
| **Alaska** | | |
| Amchitka Island (Nevada Offsite) | Aleutian Islands, AK | 2001 |
| **California** | | |
| General Atomics Site | San Diego, CA | 2000 |
| General Electric Vallecitos Nuclear Center | Pleasanton, CA | 2005 |
| Lab for Energy Related Health Research | Davis, CA | 2002 |
| Lawrence Berkeley National Lab | Berkeley, CA | 2003 |
| Lawrence Livermore National Lab Main Site | Livermore, CA | 2006 |
| Lawrence Livermore National Lab Site 300 | Livermore, CA | 2006 |
| Sandia National Labs–California | Livermore, CA | 1999 |
| Santa Susana Field Lab | Los Angeles, CA | 2006 |
| Stanford Linear Accelerator Center | San Francisco, CA | 2000 |
| **Colorado** | | |
| Grand Junction Projects Office Site | Grand Junction, CO | 2002 |
| Rio Blanco | Rifle, CO | 2005 |
| Rocky Flats Environmental Technology Site | Denver, CO | 2010 |
| **Idaho** | | |
| Argonne National Lab–West | Idaho Falls, ID | 2000 |
| Idaho National Engineering & Environmental Lab | Idaho Falls, ID | 2050 |
| **Illinois** | | |
| Argonne National Lab–East | Argonne, IL | 2002 |
| **Iowa** | | |
| Ames Lab | Ames, IA | 1999 |
| **Kentucky** | | |
| Maxey Flats Disposal Site | Morehead, KY | 2002 |
| Paducah Gaseous Diffusion Plant | Paducah, KY | 2010 |
| **Mississippi** | | |
| Salmon Site | Hattiesburg, MS | 1999 |
| **Missouri** | | |
| Kansas City Plant | Kansas City, MO | 1999 |
| Weldon Spring Site | St. Louis, MO | 2002 |
| **Nevada** | | |
| Central Nevada Test Site | Tonopah, NV | 2006 |
| Nevada Test Site | Las Vegas, NV | 2014 |
| Shoal Site | Fallon, NV | 2004 |
| Tonopah Test Range Area | Tonopah, NV | 2007 |
| **New Jersey** | | |
| Princeton Plasma Physics Lab | Plainsboro, NJ | 1999 |
| **New Mexico** | | |
| Gasbuggy | Farmington, NM | 2005 |
| Gnome–Coach | Carlsbad, NM | 2004 |
| Inhalation Toxicology Research Institute | Albuquerque, NM | 2000 |
| Los Alamos National Lab | Santa Fe, NM | 2017 |
| Sandia National Labs–New Mexico | Albuquerque, NM | 2001 |
| Waste Isolation Pilot Plant | Carlsbad, NM | 2038 |
| **New York** | | |
| Brookhaven National Lab | Upton, NY | 2006 |
| Separations Process Research Unit | Schenectady, NY | 2014 |
| West Valley Demonstration Project | Buffalo, NY | 2005 |
| **Ohio** | | |
| Columbus Environmental Management Project–West Jefferson | Columbus, OH | 2005 |
| Fernald Environmental Management Project | Cincinnati, OH | 2008 |
| Mound Plant | Dayton, OH | 2005 |
| Portsmouth Gaseous Diffusion Plant | Portsmouth, OH | 2005 |
| RMI Extrusion Plant | Ashtabula, OH | 2003 |
| **South Carolina** | | |
| Savannah River Site | Aiken, SC | 2038 |
| **Tennessee** | | |
| Oak Ridge Reservation (Y-12, ORNL, ETTP, ORR) | Oak Ridge, TN | 2013 |
| **Texas** | | |
| Pantex Plant | Amarillo, TX | 2002 |
| **Utah** | | |
| Monticello Remedial Action Project | Monticello, UT | 2001 |
| **Washington** | | |
| Hanford Site | Richland, WA | 2046 |

Management. Accelerating Cleanup: Paths to Closure. DOE/EM-0362. t of Energy, 1998. Available online at **http://www.em.doe.gov/closure/**.

changes in the past several years in coping with the massive cleanup effort, but they also say it has much left to accomplish and improve. Citing the cost of the Savannah River vitrification plant, Crowley maintains his concern about the DOE being able to make good budget, management, and technical decisions.

Yet, Cunningham notes, there are undeniable signs of progress. For instance, he says that although he saw little reason for hope only a few years ago at Rocky Flats, a severely polluted former weapons site near Denver, Colorado, "today we see actual cleanup work proceeding and in a few years, most of the major problems will be taken care of." Once the DOE can find an approach to a problem, the agency makes real progress, he adds.

Those who work with the DOE on a day-to-day basis also sound encouraged. Mitchell and his colleagues presented a paper at the DOE's annual waste management conference in Tucson, Arizona, in March 1998, that stated, "[W]e have to acknowledge a DOE that is far more open and forthcoming than at any time in the past, a DOE that is accomplishing more environmental work, even if not enough, than at any time in recent memory."

Crawford also reports that the DOE is different from what it used to be. "In the last five or six years, we sit around the table and make decisions together. We've come a long way," she says. But she emphasizes there is still much to do. For instance, the uranium-contaminated metal at Fernald does not fall neatly into any category of waste, and the cleanup may be delayed as the DOE postpones making a decision on what to do with it.

Crowley notes that the DOE can find itself under pressure from contractors who want to work and a Congress impatient for results. Yet, because the technical challenges are extremely difficult, he says, cleanup and remediation will take time, including time for exploration of alternative methods. Also, as Brush notes, there are differences in attitudes within the department that can interfere with cleanup efforts.

The DOE appears to be committed to coping with the cleanup and, with the oversight of the DNFSB, is determined to move ahead. The efforts will almost certainly be marked by both failures and successes as new technologies are tried and new management efforts are implemented. Results will also vary, depending on the characteristics at each site. But the DOE seems to have some positive momentum on its side. The issue is whether that momentum will continue as the decades of cleanup drag on and the patience of the country is put to the test.

**Harvey Karl Black**