that almost all the successful vaccines of the past have been able to multiply in the subject. A growing organism is particularly potent at stimulating all facets of the immune system. It provokes the immediate production of antibodies to neutralize the infection, stimulates the cells needed to kill infected cells, and also generates the immune memory that ensures a swift and lasting response in case of a future infection.

A live vaccine based on a weakened strain of HIV would probably be unacceptable, Ada thinks. The reason: a disabled strain of HIV might regain its virulence through mutation or genetic recombination. Several groups are trying to get around this problem by fusing antigen-producing genes from HIV into a live vector such as vaccinia, the virus that immunizes against smallpox. Similar engineered vaccines have been successfully developed against rinderpest and rabies.

But a far more radical approach was described by Reinhard Kurth of the Paul Ehrlich Institute in Frankfurt. Kurth is planning to create a strain of HIV that is more virulent than natural strains yet is incapable of establishing a long-term infection.

HIV is unusual in that it contains many genes that seem to suppress its activity. Flossie Wong-Staal, who is about to move from Gallo's lab to the University of California at San Diego, suggests that these genes may be important in allowing the virus to establish itself in the body. By damping down the virus's activity, they enable it to evade detection by the immune system. Kurth proposes getting rid of the down-regulating genes to make the virus in some sense more virulent. Deleting the *ref* gene, Kurth has shown, enables the virus to replicate ten times better. More replication, he thinks, might offer the immune system greater stimulation in the early stages of the infection, allowing it to clear the engineered HIV from the body and withstand a future invasion from real HIV.

Other genetic changes would also be needed to make the engineered strain nonpathogenic. And in addition, Kurth proposes deleting the genes that HIV uses to integrate its own DNA into the human DNA.

Would anybody volunteer to test such a vaccine? Many researchers here think a lack of volunteers might be a significant problem. Frederick Valentine, director of the AIDS clinical trials group at New York University Medical Center, sees no opposition to tests with live vaccines based on vaccinia virus or other vectors. But a live HIV vaccine, no matter how debilitated, "would be very threatening to people."

■ Jeremy Cherfas

DOE Calls in the Labs for Defense Waste Cleanup

Plans for expanding applied and basic research programs are exciting researchers. But will the funding really be there?

Energy Secretary James Watkins wants to put researchers to work cleaning up the nation's waste-laden nuclear weapons production complex. Not that scientists haven't been working on the problem—in the Department of Energy, a number of research efforts have been struggling along for years, often with marginal funding and little priority. But Watkins is an impatient—and stingy—man. He's not willing to allow the United States to spend an estimated half century and $130 billion to do a job he thinks can be done in 30 years for possibly half of that.

In fact, he's ordered up a master plan to find ways to deal with radioactive and chemical wastes where they exist, rather than digging them up and trucking them away. Said Watkins before the National Press Club on 1 August, "I am challenging our national labs to solve [the problem of] how to treat such contamination without moving it."

This initiative, which involves the preparation of a 5-year plan for applied research and a 15-year plan for basic research, is getting many chemists, engineers, geologists, and microbiologists in the research community fired up. "I think that there are going to be enormous opportunities for researchers in the academic and industrial world," says William C. Luth, a geochemist who heads the geoscience department at Sandia National Laboratories. "For the first time in the history of the agency, this area of research is being recognized at top levels as significant and important."

But despite the enthusiasm of researchers like Luth, the effort is likely to encounter formidable technical problems—and political hurdles. The research undertaking is complex because it involves low- and high-level radioactive wastes and toxic chemicals that are contaminating land and water sources to varying degrees. Solutions that may work at Savannah River, South Carolina, may not be useful in Hanford, Washington, because climate, soil conditions, and waste chemistries are different.

Also in question is whether Congress and the department itself are prepared to make a long-term commitment to expand R&D programs involving not only DOE laboratories, but also university researchers and private industry. Such support is essential, DOE officials say, if sufficient numbers of researchers and engineers are going to be attracted to work on problems related to the cleanup of defense wastes. "When you try to justify basic research with a payoff that is 10 or 15 years out, it is hard to convince people that it is a good investment," says Frank Wobber, director of DOE's subsurface science program.

The fears may be justified. In spite of publicity given to the defense waste problem last year, DOE proposed no increase in spending on basic research on cleanup technologies for fiscal year 1990. Right now, DOE is spending only $14 million a year for basic research and $150 million for applied research directly related to defense wastes.

Environmentalists also wonder whether Watkins' expectations for lowering cleanup costs are real—or just a ploy to defer budget outlays until later years. Says Jim Werner of the Natural Resources Defense Council, "Let's see them put some action behind their words."

Leo Duffy, Watkins' special assistant for defense waste management, insists that the department is committed to expanding its R&D. With the cleanup bill climbing to more than $2.4 billion in 1990 and perhaps $4.1 billion by 1995, "it is mandatory that we invest in research that might lower our costs and eliminate the hazards. Today's technology does not solve the problem," contends Duffy.

The applied research plan, which will not be unveiled until early next year, is expected to focus on developing technologies that can be deployed within 5 years to stabilize contaminated sites, restore affected lands, and reduce waste volumes produced in ongoing weapons production operations. The technologies that will top the department's list of priority projects are not yet clear, but they are likely to include a mix of approaches—some that have been toyed with for years and others that are just emerging:

■ Glassification of soils contaminated with radionuclides, heavy metals, soluble organic compounds, and inorganic ions, such as nitrites. Referred to as in situ vitrification, this technology has been under development since 1980 at Pacific Northwest

Laboratories. It involves inserting electrodes into the ground and heating the contaminated area to 1000°C to transform contaminated soils into a glass-like substance.

■ Use of fiber optic sensors to accurately identify pollutants and monitor waste levels in aquifers and to check the integrity of engineered disposal sites for high- and low-level wastes.

■ Encapsulation in polyethylene of nitrite salts and other metal-bearing wastes from defense processing plants such as Rocky Flats in Colorado. At present, cement is used to fix these wastes, but the substance is porous and prone to leaching. The use of plastic as a binder, a process developed at Brookhaven National Laboratory, is expected to greatly reduce leaching.

■ Supercritical water oxidation, a low-temperature combustion process that might be used to separate the radioactive component from the organic component in hazardous wastes. Discovered at the Massachusetts Institute of Technology about 10 years ago, the technique calls for pumping aqueous mixed wastes to pressures of 5000 pounds per square inch at 500°C in a flow reactor. Oxidation of the organics occurs as a result, and the end products—chlorine, carbon dioxide, nitrogen, and radioactive materials—are captured for recycling or treatment.

These are but a few of the technologies that DOE is pursuing; many others are still years away from deployment. Take advanced robotics, a key tool for limiting worker exposure to radiation and toxic compounds. There exist stationary industrial robots and a handful of guided machines that can perform many tasks with ease, says Sig Thunborg, an engineer at Sandia.

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Contaminated soil *that has been melted on location and converted into a stable, glass-like substance in a test at Pacific Northwest Laboratory.*

But he says the technology for intelligent robots is still at an early stage of deployment. "Sensors and software for real-time force, proximity, and vision have been developed but have not seen wide application," says Thunborg, noting that these attributes are important for robots working in hazardous environments. A special effort also may be needed, he says, to harden robots destined to work in areas of high radiation.

A potential blockbuster technology, which is in its infancy, is subsurface bioremediation—the use of microorganisms to break down hazardous chemicals that have leached deep into the ground. Researchers at Savannah River and Oak Ridge National Laboratory, for example, hope to use methane-consuming microorganisms that exist naturally in the soil to destroy chlorinated metal-cleaning solvents that have contaminated subsurface soils and aquifers at some weapons production facilities. Bench-scale bioreactor tests show that when oxygen mixed with methane or propane is pumped into the soil, naturally occurring organisms break down tetrachloroethylene and trichloroethylene in sediments as deep as 60 meters. The organisms effectively remove these compounds entirely at concentrations up to 1000 milligrams per liter.

But the risks and effectiveness of bioremediation or in situ vitrification, for example, may be hard to measure without more basic research to understand chemical, physical, and biological processes governing contaminants and their movements in complex environments.

"There is a need to consider fundamental problems such as the potential for the chemical and microbial cleanup mechanisms to increase the mobility of radionuclides," says DOE's Wobber. To do this, he says, sufficient data must be gathered to build three-dimensional predictive models. "Right now the information pipeline is virtually empty," he says. "Good contaminant transport models do not exist."

Andrew Tompson, a ground-water hydrologist at Lawrence Livermore National Laboratory, agrees. Researchers must have a better understanding of wastes, soil chemistry, and aquifers if bioremediation and chemical techniques are to be used effectively. "We need to be able to make predictions with confidence about the outcome of a treatment strategy," says Tompson.

Our understanding of subsurface systems and bioremediation methods might be more advanced, some officials say, had DOE put more money into the effort when the potential of this research was first recognized in the early 1980s. The lack of key data cannot be blamed entirely on lack of resources, however. In the case of subsurface work aimed at discovering bacteria to degrade organics, says researcher David L. Balkwill of Florida State University, even the general microbiology community was skeptical. By 1987, however, the DOE-supported research showed that relatively high populations of organisms belonging to the *Pseudomonas* family reside 500 meters underground. Some are so interesting that drug companies such as Abbott, Lilly, Pfizer, and Sterling have sought to acquire cultures from DOE.

"The latent capabilities of subsurface microbial populations and the limitations of enlisting them in cleanup missions are just beginning to be understood," says David C. White of the Institute of Applied Microbiology at the University of Tennessee. Even more promising bugs may exist at DOE's Hanford and Idaho sites. Finding answers to these questions and to whether the Savannah River organisms can work their magic at other locales will hinge on funding.

The plan being prepared by DOE's Office of Energy Research, which will set forth research priorities, will not be released until September 1990. But, a report* outlining research needs has just been completed. Meanwhile, the Office of Energy Research is holding 1990 spending on basic R&D related to hazardous and radioactive waste to 1989's level of $14 million. DOE officials told *Science* that this figure is certain to rise in 1991, but they won't say how much.

Researchers like Sandia geochemist Luth and Jack Corey, waste management coordinator at Savannah River, however, contend that at least $50 million annually needs to be funneled into basic research programs if the department wants to make rapid advances. Indeed, the University of Tennessee's White and Livermore's Tompson say that given the diversity of problems and technologies that will be needed, the government can't afford to pinch pennies. Says Tompson, "The bottom line is that billions of dollars may be riding on how well we do."

■ **Mark Crawford**

**Evaluation of Mid-to-Long Term Basis Research for Environmental Restoration* (Office of Energy Research, Department of Energy, Washington, DC, September 1989).