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Is There a Place for Nuclear Waste?

Yucca Mountain was supposed to be the answer to the U.S.'s nuclear waste problem, but after 22 years and $9 billion, that vision is dead. Now, some say that doing nothing in the near term may be the smartest solution

By Matthew L. Wald

Two weeks after President Barack Obama pulled the plug on Yucca Mountain, the site near Las Vegas where the federal government has been trying for 22 years to open a repository for nuclear waste, geochemist James L. Conca came to Washington, D.C., with an idea in his pocket.

Conca has been assigned by the state of New Mexico to monitor the environment around a different federal nuclear dump, one used for defense-related plutonium, and where others see problems, he sees opportunity.

The long battles over nuclear waste have produced much study and argument, epic legal wrangling and one mass-produced souvenir: a plastic bag labeled “Permian Age Rock Salt” that holds clear hunks of crystal mined from the Waste Isolation Pilot Plant 2,150 feet under the Chihuahuan Desert outside of Carlsbad, N. M. Conca, director of the Carlsbad Environmental Monitoring and Research Center at New Mexico State University, delights in giving away the little bags, telling recipients to hold the crystals up to the sunlight and peer through the translucent salt as if they were candling an egg.

Inside the chunks are little bubbles of water—what geologists call inclusions—that have been trapped for 225 million years, traces of a long-gone sea. They look a bit like bubbles trapped in Jell-O. Inclusions indicate how fast water, the vector for spreading waste, can move through the rock; in this case, Conca says, the timeline is encouraging. The salt naturally creeps in to close any cracks, so the water remains trapped. “Permeability is not just very low but zero,” he says. When it comes to a place to put something that will be hazardous for a million years—the wastes that were to go to Yucca, for example—“you couldn’t engineer something this good,” he observes.

Conca’s position is not shared by the elected leaders of New Mexico—if it were, the arguing would be over by now. But it is an indication that while the problem of nuclear waste remains unsolved, there are a number of reasonable candidate solutions. Some, like Carlsbad, resemble Yucca in kind if not location—find a quiet area and bury the stuff. Others rely on increasingly complex recycling schemes. But until elected officials implement an alternative plan—a process, if Yucca is any guide, that could take decades—the waste will languish at 131 storage sites around the country.

The Collapse

This delay may not be an entirely bad thing. So far, at least, the interim waste being stored on-site at power plants is well inventoried and managed. It does not cascade from storage lagoons, as a billion gallons of toxic coal wastes did from a Tennessee Valley Authority power plant in December 2008. And unlike carbon dioxide, it does not disperse into the atmosphere to be counted in worrisome parts per million, an index of climate sickness akin to the white blood cell count of an infected patient. It does, however, accumulate and linger, in some cases longer than the reactor that produced it. The waste debate has gone on so long that there are now 10 “orphan” sites, radioactive mausoleums where the power plant is gone but the waste remains.

“Waste” might not be quite the right word; technically, the term for the bulk of the material to be buried is “spent nuclear fuel.” The civilian stuff starts out as a fuel assembly—a bundle of thin-walled metal tubes, each filled with ceramic pellets of uranium oxide the size of pencil erasers. In the absence of free neutrons, this uranium is extremely stable. Power plant technicians handle the fresh fuel wearing nothing more than white gloves—and the gloves are for the protection of the fuel, not the workers.

After it arrives on site, the fuel is lowered into the outermost regions of a circular reactor vessel, which is sealed up and run for one to two years. Then the vessel is opened, the innermost, oldest fuel is removed, and the younger fuel moved toward the center. Usually a given fuel assembly will stay in the vessel for three cycles, which can last a total of anywhere from three to six years.

When a fuel assembly comes out, highly radioactive fission products such as strontium 90 and cesium 137 are generating tens of kilowatts of heat. If the assembly were cooled merely by air, the metal surrounding the nuclear material would melt; it might even burn. So the assemblies are kept submerged in a spent-fuel pool, a steel-lined concrete pool with water so clean that a drop of tap water would pollute it. These fission products burn hot but relatively quickly. Their half-life—the time it takes for half the material to transmute into more stable elements and release radiation—is measured in mere years. Heat production falls by 99 percent in the first year. It falls by another factor of five by the time the fuel is five years old and by another 40 percent by year 10.

After a few years the rods no longer need to be stored in water. They are transferred into steel sleeves, then drained, dried, pumped full of an inert gas and sealed. The sleeves are loaded into giant concrete casks and put into on-site storage near the reactor. Inside its concrete-and-steel silo, the fuel produces so little heat that it can be cooled by the natural circulation of air.

The long-term challenge is dealing with the actinides, materials created when uranium absorbs a neutron but refuses to split apart. These elements have half-lives in the hundreds of thousands of years. The Department of Energy originally set out to demonstrate that Yucca was safe for 10,000 years, yet it acknowledged that peak radiation releases would come after about 300,000 years. Opponents seized on that disparity, and in 2004 the U.S. Court of Appeals for the Federal Circuit ruled that the DOE had to demonstrate that the waste could be stored safely for one million years.

Yucca was never the leading candidate from a scientific point of view. A volcanic structure, it became the leading candidate when it was chosen in 1987 by the best geologists in the U.S. Senate. Before politicians stepped in, aiming to speed up the selection process and also to guarantee that the waste would not go anywhere else, Yucca was on a list of possible locations, along with sites in Texas and Washington State. The DOE and its predecessor agency put these sites on the list for their scientific promise and partly for reasons of convenience—in the case of Yucca Mountain, the federal government already owned the place, and it was adjacent to a nuclear weapons test site.

Yucca fell out of the running for pretty much the same reason: politics. In 1987 the speaker of the House was a Texan, Jim Wright, and so was the vice president, George H. W. Bush. The House majority leader was Tom Foley of Washington State, and Harry Reid was a first-term senator from Nevada. Washington State and Texas dropped off the list. Now Reid is the majority leader, and the president won Nevada’s four electoral votes partly by promising a new look at nuclear waste. The politics of geology has changed.

A purely scientific evaluation of competing geologies might find a better choice. “Salt is nice, in some senses, from a geologic perspective,” says Allison M. Macfarlane, a geochemist and assistant professor of environmental science and policy at George Mason University and a frequently mentioned candidate for a vacant seat on the Nuclear Regulatory Commission. But if the salt is heated, the watery inclusions mobilize and flow toward the heat, she points out, so burying spent fuel there would require waiting until the hot waste products cool down a bit—somewhere around the second half of this century.

Macfarlane helped to organize a conference called “Toward a Plan B for U.S. High-Level Nuclear Waste Disposal” in July 2007, an event that mostly demonstrated that there was no plan B. The U.S. could find another solution, though, she says, if it used a more open, fair process for choosing sites—in other words, if it took the choice away from the politicians.

Plan B

It was never supposed to come to this. The Nuclear Waste Policy Act of 1982 specified that utilities had to pay into a government-administered Nuclear Waste Trust Fund a tenth of a cent for every kilowatt-hour of energy their reactors generated. The government, in turn, agreed to find a place to bury the waste. The DOE forced the utilities to sign contracts and promised to begin taking deliveries in January 1998.

Before President Obama submitted his 2010 budget, cutting funding for Yucca Mountain to a perfunctory $197 million, the official opening date was scheduled for 2017. And the department estimated that as of that date, it was liable for damages of $7 billion to the utilities, possibly the world's largest late fee. The price rises by $500 million every additional year of delay. If the science and engineering can come together, a fix is worth a lot of money.

Another possible solution revisits a decision made over three decades ago. By volume, about 95.6 percent of the spent fuel that comes out of a reactor is the same uranium oxide in the original fuel. The rest of the spent fuel is made of hot fission products (3.4 percent) and long-lived actinides such as plutonium (1 percent). At the start of the nuclear age, the plan was to recycle the uranium and plutonium into new fuel, discarding only the short-lived fission products. In theory, this would reduce the volume of waste by up to 90 percent. But President Gerald Ford banned recycling in 1976, and his successor, President Jimmy Carter, a former officer in the nuclear navy, concurred. The reason they gave was proliferation risk—the plutonium could also be used for bombs, so the reprocessing technology would be risky in Third World hands. (The economics have also been unfavorable.)

With the Ford decision, the U.S. committed itself to an "open" fuel cycle, meaning that the fuel would make a one-way trip—cradle to grave—as opposed to a "closed" cycle, where much of the fuel would have made a second or third pass through the reactor. It also made questions over waste a perennial part of the nuclear conversation. Various proposals have been floated over the years. Some have advocated shooting the stuff into space (a challenge, given its weight and the less-than-perfect success rate of launch vehicles). Others have suggested burying the waste at the borders of geologic plates and letting it slide over the eons back into the earth's mantle.

Instead it is filling up spent-fuel pools and then being shifted into dry casks, the steel-lined concrete silos. Although dry-cask storage might seem like a precarious and accidental solution, there is much to recommend it. Barring an accident such as dropping the sleeve on the racks of fuel in the pool, not much can go wrong. A terrorist attack could conceivably breach a cask, but the material inside is still a solid and is unlikely to go far. A terrorist group with a few rocket-propelled grenades and the talent to aim them well could find far more devastating targets than dry casks.

Storage space is also not an immediate concern. "There is enough capacity on our existing nuclear plants, if not for the rest of the century, then for a good portion of it," says Revis James, director of the Energy Technology Assessment Center at the Electric Power Research Institute, a utility consortium based in Palo Alto, Calif. "You could survive with aboveground storage for quite a while." Moreover, he says, "we're talking about a volume of waste that in the greater scheme of things is pretty small." (According to the International Atomic Energy Agency, a 1,000-megawatt reactor produces about 33 tons a year of spent fuel—enough to fill the bed of a large pickup truck.) As we face the threat of global warming, it would be a mistake to dismiss nuclear energy—an energy source that produces no greenhouse gases—on the basis of waste, he argues.

In addition, waste is a changing thing. The longer it is held in interim storage, the more material decays and the easier it is to deal with. While existing federal law sets the capacity of Yucca in terms of tons of waste, the real limit is heat. If the fuel is hot enough and packed closely enough to boil the groundwater, it will create steam that can fracture the rock, increasing the speed with which waste can eventually escape. The older the fuel, the lower the heat output and the smaller the repository required. (Or rather the smaller the *number* of repositories required—by 2017 the U.S. will already have accumulated far more nuclear waste than Yucca was legally supposed to take.)

As a result, dry-cask storage has shifted from its original role as a short-term solution to a viable medium-term solution. Existing reactors operate under a "waste confidence" doctrine, which says that while there is no repository now, there is "reasonable assurance" that there will be one by 2025. With that position now untenable, the Nuclear Regulatory Commission's staff has drafted new language, saying that the waste can be stored in casks for decades at reactors with no environmental effect, until burial is available. The change should make it easier to construct new reactors even in the absence of a long-term plan for the waste they will produce.

Not everyone is so sanguine. Arjun Makhijani, president of the antinuclear group Institute for Energy and Environmental Research, filed dissenting language with the commission earlier this year. He argued that it is irresponsible to assume that acceptable burial sites will one day become available. “A scientific explanation of the term ‘reasonable assurance’ requires either physical proof that such a [long-term storage] facility exists,” he wrote, or firm evidence that one could be built using existing technology. Yet there is no validated model of any facility that proves that the waste is highly likely to stay isolated for hundreds of thousands of years, he says.

Others object to long-term storage on the surface. Certainly the nuclear power industry would like the government to put the waste underground, out of sight and out of mind. Keeping the stuff on the surface also means kicking the ball down the road for future generations. “I think it’s a cop-out,” Macfarlane says “I think we need to work toward a solution.” Surface storage means institutional control, she says: “We have no guarantee what the government is going to be 100 years from now or if there’s going to be one.”

Accelerated Breakdown

There is another alternative: hurrying up the decay chain. Although nuclear recycling facilities of the kind rejected by the U.S. in the 1970s can recycle only the plutonium in spent fuel, plutonium is just one of a dozen or so long-lived actinides. A broader solution is industrial-grade transubstantiation: using a new kind of reactor to break down the actinides [see “Smarter Use of Nuclear Waste,” by William H. Hannum, Gerald E. Marsh and George S. Stanford; Scientific American, December 2005].

General Electric is promoting a “fast reactor” that breaks up actinides with high-energy neutrons—the same subatomic particles that sustain the chain reactions in the current generation of reactors, only moving at a much higher speed. “It reduces volume on the order of 90 percent and cuts the half-life to less than 1,000 years instead of hundreds of thousands of years,” says Lisa Price, GE Hitachi Global’s senior vice president of nuclear fuel. “That can change the characteristics of what the long-term disposal site ultimately has to be.” (The calculation assumes reuse of the recovered uranium, too—something that is very difficult in conventional reactors.)

But this solution requires one new fast reactor for every three or four now running to process the spent fuel, a tough challenge at a time when the industry is having trouble simply resuming construction of the kind of reactor it built 30 years ago. One of the main arguments against such reactors is cost—a fast reactor is cooled by molten sodium rather than water, and the advanced design is estimated to cost anywhere from $1 billion to $2 billion more per reactor than a similarly sized conventional reactor [see “Rethinking Nuclear Fuel Recycling,” by Frank N. von Hippel; Scientific American, May 2008]. Democrats in Congress blocked most funding for fast reactors late in the Bush administration, and President Obama does not favor them.

Finally, Yucca could always come back. “Thirty-nine states have high-level waste—either civilian spent nuclear fuel or Navy spent nuclear fuel or defense program high-level waste,” says Edward F. Sproat III, who was the DOE official in charge of the Yucca project for the last two and a half years of the Bush administration. The waste is “all destined to go to Yucca, and there’s no other place to send it.” He and others argue that President Obama and Senator Reid have the political power to block funding but not to change the 1987 amendment to the Nuclear Waste Policy Act that targets Yucca exclusively. And if Congress debates where else to put it, he says, “everybody knows their state is going to be back in play.”

Note: This article was originally printed with the title, "What Now for Nuclear Waste?"

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