The Witch of Yucca Mountain

More research on nuclear waste storage won't reassure the public

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mirrored from
Technology Review Online
Technology for Presidents

March 12, 2004

There is an almost primal fear of radioactivity. It may be a new manifestation of an old Jungian archetype: the fear of unseen danger, perhaps originally a predator or enemy lurking in ambush. Other incarnations include the fear of witches, germs, communists, and monsters under our beds. But radioactivity is worse. Not only is the threat hidden, but so is the attack. Your genes are invisibly mutated, showing no sign of the assault until a decade or two later when the damage manifests itself in a growing cancer.

I put radioactivity on this witch list in an effort to make sense of the furor over nuclear waste storage at the Yucca Mountain facility in Nevada. When I work out the numbers, I find the dangers of storing our waste there to be small compared to the dangers of not doing so, and significantly smaller than many other dangers we ignore. And yet a contentious debate continues. More research is demanded, and yet every bit of additional research seems to raise new questions that exacerbate the public's fear and distrust.

I've discussed Yucca Mountain with scientists, politicians, and many concerned citizens. The politicians believe it to be a scientific issue, and the scientists think it is a political one. Both are in favor of more research -- scientists because that is what they do, and politicians because they think the research will answer the key questions. But I don't think it will.

Let me review some pertinent facts. The underground tunnels at Yucca Mountain are designed to hold 77,000 tons of high-level nuclear waste. The most dangerous part of this consists of "fission fragments" such as strontium-90, the unstable nucleius created when the uranium nucleus splits. Because this isotope has a shorter half-life than uranium, the waste is about a thousand times more radioactive than the original ore. It takes 10,000 years for the waste (not including plutonium, which is also produced in the reactor, and which I'll discuss later) to decay back to the radioactive level of the mined uranium. Based largely on this number, people have searched for a site that will remain secure for 10,000 years. After that, we are better off than if we left the uranium in the ground, so 10,000 years of safety is clearly good enough.

How can we plan to keep Yucca Mountain secure for this long? What will the world be like 10,000 years from now? Think backwards in order to appreciate the time involved: ten thousand years ago humans had just discovered agriculture, and writing wouldn't be invented for another 5,000 years.

Can we possibly see 10,000 years into the future? No. It is ridiculous to think we could. So nuclear waste storage is obviously unacceptable. Right?

Of course, calling storage unacceptable is itself an unacceptable answer. We have the waste and we have to do something with it. But the problem isn't really as hard as I just portrayed it. We don't need absolute security for 10,000 years. A more reasonable goal is to reduce the risk of leakage to 0.1 percent, i.e. to one chance in a thousand. Since the radioactivity is only 1,000 times worse than that of the uranium we removed from the ground, that means that the net risk (probability times danger) is 1,000 x 0.001 = 1, that is, basically the same as the risk if we hadn't mined the uranium in the first place. (I am assuming the unproven "linear hypothesis" that total cancer risk is independent of individual doses or dose rate, but my argument won't depend strongly on its validity.)

Moreover, we don't need this 0.1 percent level of security for the full 10,000 years. After 300 years, the fission fragment radioactivity will have decreased by a factor of 10; it will only be 100 times as great as the mined uranium. So by then, we should rationally require only a 1 percent risk that all of the waste leaks out. That's a lot easier than guaranteeing absolute containment for 10,000 years. Moreover, this calculation assumes 100 percent of the waste escapes. For leakage of 1 percent of the waste, we can accept a 100 percent probability. The storage problem is beginning to seem tractable.

But the unobtainable and unnecessary criterion of absolute security dominates the public discussion. The Department of Energy continues to search Yucca Mountain for unknown earthquake faults, and many people assume that the acceptability of the facility depends on the absence of any such faults. Find a new fault—rule Yucca Mountain out. But the issue should not be whether there will be an earthquake in the next 10,000 years, but whether there will be a sufficiently large earthquake in the next 300 years to cause 10 percent of the waste to escape its glass capsules and reach ground water with greater than 1 percent probability. Absolute security is too extreme a goal, since even the original uranium in the ground didn't provide it.

But why compare the danger of waste storage only to the danger of the uranium originally mined? Why not compare it to the larger danger of the uranium left in the ground? Colorado, where much of the uranium is obtained, is a geologically active region, full of faults and fissures and mountains rising out of the prairie, and there are about a billion tons of uranium in its surface rock. (This number is based on the fact that granite typically contains 4 parts per million of uranium. I take the area of the Colorado Rockies to be about 300 by 400 kilometers, and consider only rock from the surface to 1,000 meters depth.) The radioactivity in this uranium is 20 times greater than the legal limit for Yucca Mountain, and will take more than 13 billion years—not just a few hundred—for the radioactivity to drop by a factor of ten. Yet water that runs through, around, and over this radioactive rock is the source of the Colorado River, and is used for drinking water in much of the west, including Los Angeles and San Diego. And unlike the glass pellets that store the waste in Yucca Mountain, most of the uranium in the Colorado ground is water-soluble. Here is the absurd-sounding conclusion: if the Yucca Mountain facility was at full capacity and all the waste leaked out of its glass containment immediately and managed to reach ground water, the danger would still be 20 times less than that currently posed by natural uranium leaching into the Colorado River.

I don't mean to imply waste from Yucca Mountain is not dangerous. The Colorado River example

only illustrates that when we worry about mysterious and unfamiliar dangers, we sometimes lose perspective. Every way I do the calculation, I reach the same conclusion: waste leakage from Yucca Mountain is not a great danger. Put the waste in glass pellets in a reasonably stable geologic formation, and start worrying about real threats—such as the dangers of continued burning of fossil fuels.

A related issue is the risk of mishaps and attacks while transporting nuclear waste to the Yucca Mountain site. The present plans call for the waste to be carried in thick reinforced concrete cylinders that can survive high-speed crashes without leaking. In fact, it would be very hard for a terrorist to open the containers, or use the waste in radiological weapons. The smart terrorist is more likely to hijack a tanker truck full of gasoline, chlorine, or some other common toxic material and then blow it up in a city.

So why are we worrying about transporting nuclear waste? The answer is ironic: we have gone to such lengths to assure the safety of the transport that the public thinks the danger is even greater. Images on evening newscasts of concrete containers being dropped from five-story buildings, smashing into the ground and bouncing undamaged, do not reassure the public. This is a consequence of the "where there's smoke there's fire paradox" of public safety. Raise the standards, increase the safety, do more research, study the problem in greater depth, and in the process you will improve safety and frighten the public. After all, would scientists work so hard if the threat weren't real?

Well-meaning scientists sometimes try to quench the furor by proposing advanced technological alternatives to Yucca Mountain storage, such as rocketing the waste into the sun, or burying it in a tectonic subducting zone at sea, where a continental plate will slowly carry it into the deep Earth. Such exotic solutions strongly suggest that the problem is truly intractable, and they only further exacerbate the public fear.

Let me return now to the danger of the plutonium in the waste. Plutonium is not a fission fragment; it is produced in the reactor when uranium absorbs neutrons. But unlike the fission fragments, plutonium doesn't go away by a factor of 10 in 300 years; its half-life is 24,000 years. Not only that, but many people think plutonium is the most dangerous material known to man.

Plutonium is certainly dangerous if you make nuclear weapons out of it. If turned into an aerosol and inhaled, it is more toxic than anthrax—and that's very toxic. But when ingested (e.g. from ground water) it isn't. According to the linear hypothesis, when consumed by a group of people, we expect about one extra cancer for each half-gram of plutonium swallowed. (Click here for a good reference.) That is bad, but not a record-setter. Botulism toxin (found in poorly prepared mayonnaise) is a thousand times worse. The horrendous danger of ingested plutonium is an urban legend—believed to be true by many people, yet false. Moreover, I think it a mistake to bury the plutonium with the waste. It is a good fuel for reactors, as valuable as uranium. I sense that original reason for burying it (rather than extracting and using it) was to keep the public from worrying about it, but that approach has backfired.

By any reasonable measure I can find, the Yucca Mountain facility is plenty safe enough. It is far safer to put the waste there than to leave it on site at the nuclear plants where it was made and is currently stored. We should start moving it to Yucca Mountain as soon as possible. Research

should continue, because more knowledge is good, but the hope that it will reassure the public is forlorn. Further studies are no more likely to reduce public concern now than scientific research would have calmed the fears of the people of Salem in 1692.

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