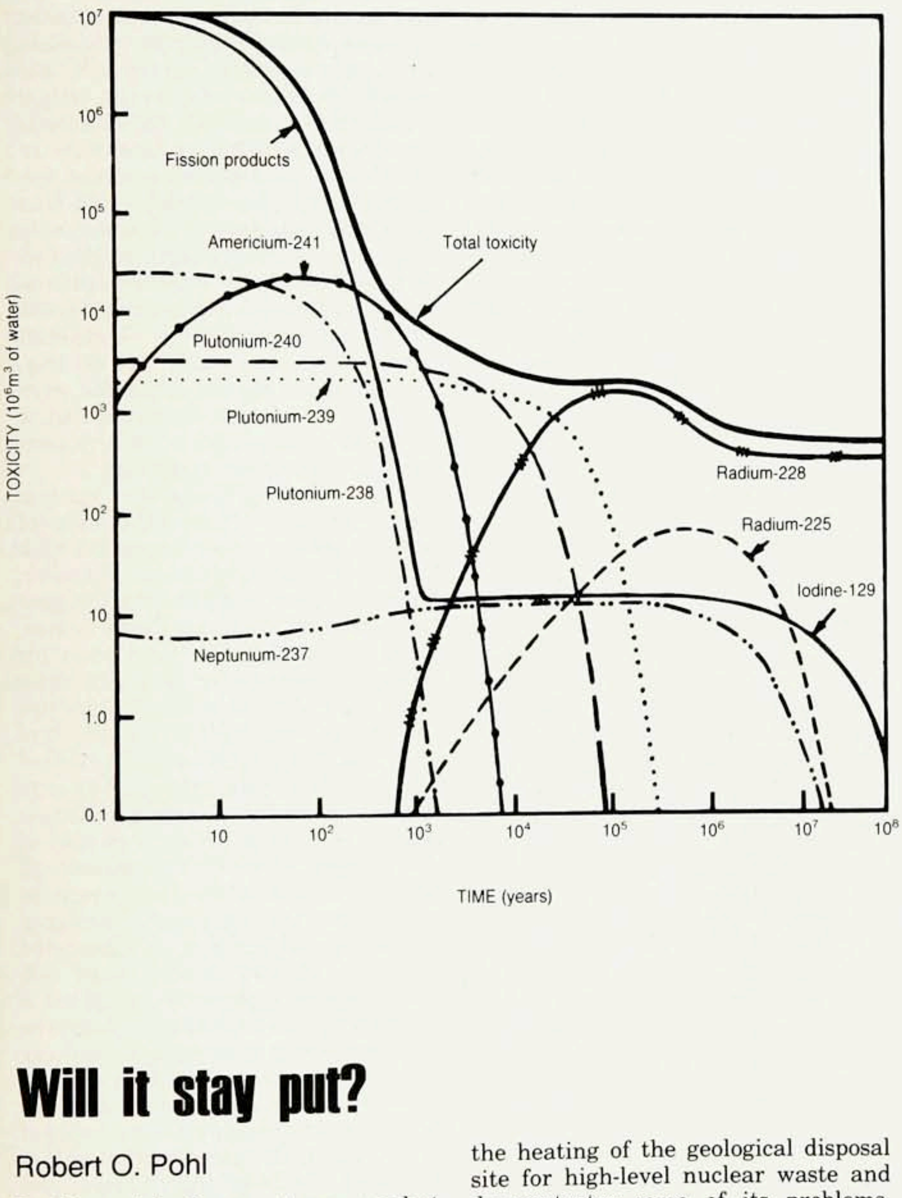
waste disposal



Radioactive waste: how long a danger? Toxicity as a function of time for fission products and transuranic isotopes. Toxicity is given in cubic meters of water required to dilute the waste to the maximum permissible concentration for drinking water standards. Figure 1

Will it stay put?

Robert O. Pohl

In this article I present a somewhat detailed discussion of four examples of nuclear waste policy issues, in the hope that this may better convey an idea of the complexity of the entire topic. The first will show how drastically our perception of the waste-disposal issue has changed in recent years, and should thus teach us some caution with regard to our present understanding. The second is geotechnical: It concerns the heating of the geological disposal site for high-level nuclear waste and demonstrates some of its problems. The third concerns uranium mill tailings and will show the environmental risks posed by the very large volumes of low-level radioactive wastes. The last example will address the least predictable aspect of long-term management of nuclear wastes: future human activities, and how they affect the proper planning of nuclear waste disposal.

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Changing perceptions in technology

In the early days of the nuclear age, the waste problem appears to have been entirely ignored. In a 1950 publication by the AEC, for example, radioactive wastes were considered a valuable resource, to be preserved for some unspecified later use.[1] Consequently, the high-level waste problem was nonexistent! In this publication the following treatment of high-level radioactive waste was envisioned:

> The irradiated products of reactors contain high-level radioactivity. These wastes have been called the ashes of the nuclear furnace but they cannot be disposed of as ordinary ashes. The most highly radioactive wastes are those remaining after the product desired, such as plutonium, is removed from the irradiated fuel by chemical separation processes. These wastes contain various fission products and inadequately irradiated uranium. They are highly dangerous because of their radioactivity. They are extremely valuable because of the recoverable uranium and other important materials they contain. Currently, these highly dangerous wastes are stored, but ways and means of recovering the valuable products in them are subject to much investigation. After certain cycles of decontamination have been completed the level of radioactive contamination drops very materially. As in the case of other wastes, a point is finally reached at which a decision must be made between the economics of further decontamination and the realities as to public health risks involved in release of these wastes to nature. Under present circumstances prudence dictates a conservative course of action in favor of protection of public health.

Seven years later this view had changed. In 1957 an ad hoc panel

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This heat is produced principally by decay of the fission products, and diminishes rapidly during the first few hundred years.[4]

Considerable research has gone into developing containment packages that would isolate the waste successfully within the underground facility for at least 1000 years. Although the short-lived fission products such as strontium-90 and cesium-137 have an extremely large ingestion hazard immediately after being removed from the reactor, their ingestion hazard after 1000 years actually falls below that of natural uranium ore.[5] (The ingestion hazard is stated in terms of the amount of water required to dilute the waste to the maximum permissible concentration for current drinking water standards.)

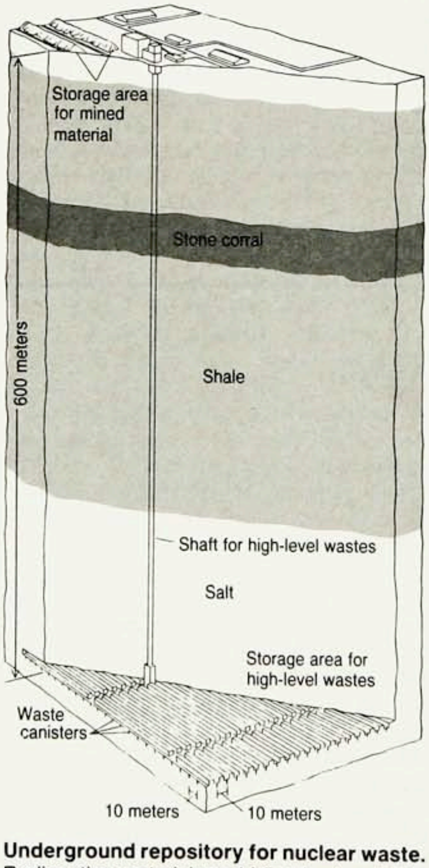
Before the high-level waste would be emplaced in the repository, it would first be incorporated with some material, possibly a glass or a ceramic, with three parts of this material to one part of waste. Rugged stainless-steel canisters thirty centimeters in diameter by three meters in length which are tested for resistance to corrosion and heat would be used to mold and contain the solid waste form. The waste produced by a reactor operating for one year would fill about ten of these canisters. The canisters would be lowered into the underground facility and emplaced beneath the floor of the facility. All excavated cavities and shafts would then be refilled with the rock material removed during excavation, and sealed.

Salt deposits are a leading candidate for nuclear-waste disposal for several reasons. They conduct waste heat rapidly away from the canisters because of the relatively high heat conductivity of salt. In addition, salt beds are easily mined and are believed to lack any subsurface water that could dissolve the salt. However, there are certain potential problems with the long-term stability of salt over several hundred thousand years, such as mechanical stresses caused by heat and possible changes in the groundwater regime, which have raised interest in other geologic media, such as granite. Furthermore, although salt conducts heat away from the canisters about twice as fast as granite, the maximum temperature developed in granite could in fact be lower than that in salt: Granite has a greater capacity to store heat, which more than offsets the higher heat conductivity of salt. Moreover, a rock such as granite does not have the problems of mechanical stability or brine migration that reduce the attractiveness of bedded salt.

Currently the federal government is studying the salt beds near Carlsbad, New Mexico, hoping to establish the country's first demonstration waste disposal site by 1990.[6] Under the Waste Isolation Pilot Plant (WIPP) project, scientists are analyzing a region of salt beds more than 200 million years old to identify some eighty square kilometers that would be acceptable for the demonstration site. Although the WIPP is designed primarily for the storage of military wastes, the government is also considering the use of twenty acres for the emplacement of 1000 commercial spent fuel assemblies, or the amount produced by one reactor operating for thirty years. Information obtained from this experiment would be used in the design of a bedded salt repository for commercial waste. Potential problems at the Carlsbad site are the subject of intensive study and discussion. The determination of the site's acceptability, as with any potential repository site, will require significant understanding of the geologic system and must include an assessment of all events and processes that can significantly influence it.[7,8]

Keeping the waste isolated

Once a repository has been backfilled and sealed for permanent isolation, the radioactivity in the waste could return to the Earth's surface only if the rock mass containing the waste were physically moved from the waste site or exhumed, or if the waste were dissolved and transported back to the biosphere by groundwater moving through cracks and pores in the rocks.[5] Either natural processes such as erosion, volcanic eruption, and meteorite impact, or human activities such as drilling for mineral resources, could conceivably result in our exposure to the buried radioactive waste. To prevent this, stringent guidelines are needed to reduce significantly the probability that any event might breach the repository.[9] These criteria would require that the facility be located away from known areas of volcanic activity, for example, and that the excavated cavity be sufficiently deep so that surface erosion or meteorite impact could not exhume radionuclides from the underground repository. The possibility of accidental human intrusion, such as drilling, could be made remote if the site were so devoid of mineral resources that it would be unattractive to future generations mining for resources.



Underground repository for nuclear waste. Radioactive material would first be fused into water-resistant glass blocks and sealed in stainless-steel canisters and then deposited deep underground (about a third of a mile) in a stable geologic medium, such as rock salt. Canisters are spaced from each other to control heat buildup. Figure 2

When one first hears that nuclear waste must be isolated for thousands of years, it seems a near-impossible task for any human institution. However, we must realize that although the time scale for institutions on Earth is measured in decades, the time scale for geologic processes is typically measured in millions of years. Nature has given us an example where radioactive wastes did not migrate over a period of many million years. The world's only known naturally occurring nuclear reactor is located in the republic of Gabon, West Africa.[10] The presence of fission products in the Oklo uranium deposit provide convincing evidence that a natural reactor once operated there, nearly two billion years ago. Groundwater apparently saturated a body of uranium ore and moderated the neutrons being generated in the ore sufficiently to create a small nuclear chain reaction. (The presence of water moderates or slows down the velocity of neutrons, which increases the rate of fissioning.) Most of the radionuclides remained immobilized in the uranium ore even though the nuclear reactor lasted for hundreds of thousands of years and created a complete distribution of fission products. This example provides good evidence that low mobility of radionuclides might be expected in nature. Of course, the conditions in actual repository sites would not be identical, and each site needs to be evaluated individually.

There appears to be general agreement that groundwater is the most

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assembled by the National Academy of Sciences considered the disposal of high-level radioactive liquid wastes in a mined geologic disposal site. This panel found that "Disposal in cavities mined in salt beds and salt domes is suggested as the possibility promising the most practical immediate solution of the problem. Disposal could be greatly simplified if the waste could be gotten into solid form of relatively insoluble character."

This philosophy of disposal was followed when the AEC proposed its first disposal site to be constructed in an abandoned salt mine in a bedded salt formation in Lyons, Kansas. The records of the 1971 congressional hearing on the AEC authorizing legislation make interesting reading.[2] They are filled with assurances by officials from the AEC and their technical experts from the Oak Ridge National Laboratories that the proposed method of disposal and its scientific and technical bases were sound. Furthermore this particular site would provide the optimum solution to the nuclear waste problem.

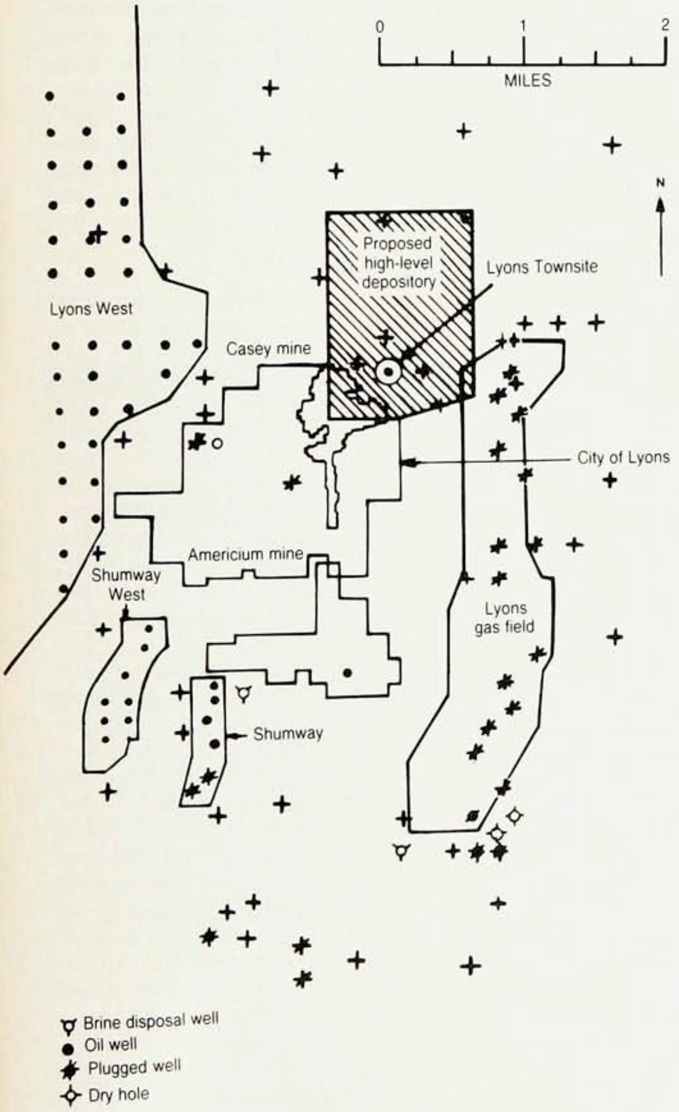
When the Lyons project was cancelled in 1972, two severe technical problems in particular had become apparent: The area in which the proposed disposal site was to be located was literally riddled with drill holes and cavities from numerous mining activities, as shown in figure 3. If all holes could not be found and permanently sealed—which was doubtful—long-term integrity of the site could not be guaranteed. The other discovery was the existence of small pockets of brine in the salt, trapped probably when the salt beds formed from drying-up oceans that had previously covered this area. These inclusions constituted, on average, only a fraction of a percent of the salt formation, but it was discovered that they migrated toward the emplaced source of heat (the simulated waste) and corroded the metal canisters. This discovery demonstrated that nuclear waste in such a salt formation would surround itself with a highly corrosive, hot liquid, which would rapidly corrode the steel canister containing the solidified waste.

As the research into improved disposal methods continued, other problems developed about the proper choice of the form in which the waste was to be buried. The most durable solid waste form considered by the AEC up to 1972 was to be achieved by fusing the waste into glass blocks, which would provide a barrier against dissolution (even by hot brine). In 1973, however, J. E. Mendel and I. M. Warner at the Battelle Pacific Northwest Laboratories, discovered that the dissolutioning of glass was strongly temperature dependent.[4] At temperatures above 100 °C the leach rate of glass in water increased very rapidly. These measurements have since been extended to higher temperatures, and also to hot brine, and it has been shown that under these conditions glass provides essentially no barrier against dissolution. These findings have influenced many of the current research activities. Materials scientists and geochemists are working to encapsulate the waste in more stable (that is, less leachable) waste forms, such as crystalline ceramics ("Super Calcine") or synthetic rocks ("SYNROC"), but none has yet progressed beyond the laboratory stage, and the debate continues about their relative merits.

Also, according to the plans of the AEC in 1971 the solidified wastes were to be sealed in steel canisters that were only expected to provide protection during transportation and emplacement in the Lyons disposal site. This view has also changed. Recently the NRC has proposed that waste packages should instead by designed "so that there is reasonable assurance that radionuclides will be contained for at least the first 1000 years after decommissioning."[5] I doubt whether any of the waste forms considered can be shown to satisfy this criterion alone, and disposal methods will consequently call for further engineered barriers, such as canisters, overpacks and buffers, to prevent a chemical attack of the waste by groundwater for at least the first 1000 years.

While rock salt had been considered since 1957 to be the prime geological disposal medium, attention is now also directed toward other rocks, including granite, basalt, gneis, clay, tuff, and anhydrite, so as to avoid brine, which has been recognized as the "universal solvent."

While this brief historical review cannot be anything but a thumbnail



Abortive attempt to store nuclear waste. The proposed federal repository for waste at Lyons, Kansas, proved a major source of embarassment to the AEC when it was discovered that numerous forgotten oil and gas drillings riddled the area. Not only would holes compromise the security of the radioactive wastes but their existence suggests that, in the future, mining companies looking for mineral deposits might disturb site. Figure 3

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