LETTERS

More on Radioactive Waste Disposal: Other Approaches Proposed, Discussed

Having spent 17 years at a site heavily involved in nuclear waste and cleanup operations, I found your June 1997 special issue on nuclear waste interesting and informative. But in regard to William Kastenberg and Luca Gratton's article, "Hazards of Managing and Disposing of Nuclear Waste" (page 41), aren't we kidding ourselves when we claim to be so concerned about the far-out possibility that a nuclear waste disposal site may begin to leak ten thousand or a million years from now? In what other area of life do we show such foresight?

Letters submitted for publication should be addressed to Letters, PHYSICS TODAY, American Center for Physics, One Physics Ellipse, College Park, MD 20740-3843 or to ptletter@aip.acp.org (using your surname as "Subject"). Please include your affiliation, mailing address and daytime telephone number. We reserve the right to edit letters.

It's not as though we were knowingly setting up some distant future generations for disaster. To the best of our considerable knowledge about geology, hydrology and mineralogy, the nuclear waste dumps as planned will not ever cause a problem. On the other hand, in 50 years, more or less (to the best of that same knowledge), our liquid and gaseous fossil fuel resources will be showing signs of exhaustion (as reflected in steadily higher recovery costs and prices). And solar and wind power, though destined to fill a larger niche than at present, will never be capable of producing the massive amounts of energy needed for transportation and industry.

Our concerns are truly misplaced.

JOHN E. TANNER JR
(pust@srv.net)
Idaho Falls, Idaho

Your five articles on radioactive waste are timely and informative, but I am surprised that you did not devote a separate article to the most challenging topic, the transmutation of high-level waste. This topic is only touched upon, in Kevin Crowley's article "Nuclear Waste Disposal: The Technical Challenges," but not enough to expose the R&D efforts now in progress. Three recent conferences devoted to transmutation of high-level waste were not even mentioned.[1]

The conference proceedings make it clear that the major design work on transmutational devices is concentrated at three research centers: Los Alamos National Laboratory in the US, the International Center of Nuclear Research in Switzerland and the Japan Atomic Energy Research Institute. The proposed devices, called hybrid systems, consist of subcritical

continued on page 87

 (continued from page 15)

nuclear reactors, in which radioactive materials are destroyed by neutrons, and of powerful accelerators of charged particles—for example, protons of 1 GeV and 100 mA. In the process of slowing down, each proton entering the reactor will produce, on average, about 25 swift neutrons while the number of secondary neutrons (those produced through fission) will be much higher.

Although it may be true, as Crowley says (page 38), that "decades of additional work will be needed to determine whether transmutation can be made practical and cost effective," the topic is certainly of great interest and worth describing. I am sure that many of your readers would be fascinated to learn more about the technology of nuclear incineration of radioactive waste.

References

1. *International Conf. on Accelerator-Driven Technologies and Applications*, E. D. Arthur, A. Rodriguez, S. O. Schribner, eds., AIP Conf. Proc. **346**, AIP Press, Woodbury, N. Y. (1994); the conference was held in Las Vegas in July 1994. *Global 1995: An International Conf. on Evaluation of Emerging Nuclear Fuel Cycle Systems* (1995); the conference, a meeting of the American Nuclear Society, was held in Versailles, France, in September 1995. *Second International Conf. on Accelerator Driven Transmutation Technologies*, H. Condé, ed., Uppsala University, Uppsala, Sweden; the conference was sponsored by the International Atomic Energy Agency and held in Kalmar, Sweden, in July 1996.

LUDWIK KOWALSKI
(kowalskil@alpha.montclair.edu)
Montclair State University
Upper Montclair, New Jersey

I would like to raise four specific points that seem to have been missed in your special issue.

In John Ahearne's article, "Radioactive Waste: The Size of the Problem," the table showing isotopes in commercial spent fuel (page 26) is irrelevant. About 55% of the 14.45×10^9 curies listed in the table are from isotopes of such short halflives that they are nearly completely decayed before the end of the minimum three-year storage period in a reactor's spent fuel storage pool. In fact, one of them, praseodymium-144, has a halflife so short, 17.3 minutes, that there is not even enough time to discharge it from a reactor before it has decayed.

In "Unsolved Problems of Radioactive Waste: Motivation for a New Paradigm," Warner North raises the issue of maintaining pool storage of commercial nuclear fuel, and he states that it "becomes quite expensive after a reactor ceases operation and pool maintenance costs must be charged against storage rather than reactor operation" (page 48). The cost of storage is independent of whether a reactor is operating or not; it is just a question of allocation of those costs—that is, who pays. What is more important to note is that the utilities are impatient for the US government to take over the task of storing spent nuclear fuel. The utilities have had to do that under law, in addition to paying the US government a tax of 1 mill/kWh for many years (amounting to hundreds of millions of dollars per year). Finally, in return, the Department of Energy is now obligated by law and recent judicial decisions to begin taking spent reactor fuel starting in 1998.

No discussion of long-term storage of radioactive waste is complete without mention of the Oklo phenomenon. Oklo—located in Gabon—is a natural deposit of uranium ore that produced a natural reactor several billion years ago.[1] It has been possible to trace the migration of the resultant fission products. The actinides appear to have migrated only a few tens of meters in all this time. Here is a real example of radionuclide dispersal in the environment over billions of years under highly unfavorable conditions (Oklo is situated near the surface in the West African rain forest).

Finally, there is insufficient discussion in the special issue of the Nuclear Test Site (NTS), located not far from Yucca Mountain in Nevada. NTS is the military site where nuclear weapons were tested underground. The tests resulted in a large number of bomb cavities with fused-glass-like sides and bottoms. Because the site is already contaminated, disposing of radioactive wastes by injecting them into the already highly radioactive cavities would probably result in little incremental hazard, and perhaps far fewer political problems. No systematic study of this option seems to have been made.

Reference

1. R. Naudet, *Oklo: Des reacteurs nucleares*, Commissariat de l'Energie Atomique, Paris (1991).

FRANK RAHN
(bno21@aol.com)
Palo Alto, California

Regarding nuclear waste disposal (as discussed in your special issue) and nuclear hazards in general, hundreds of studies have confirmed what was a totally unexpected discovery: Low-level radiation is not only harmless but actually beneficial,[1,2] a phenomenon known as radiation hormesis.

The benefits of low-level radiation for mammals include increased life spans, greater reproductive capacity, better disease resistance, increased growth rates, greater resistance to higher radiation doses, better neurological function, better wound healing and lower tumor induction and growth.[1]

For humans, specifically, low-level radiation exposure is found to reduce cancer incidence and lead to longer lives.

Low-level radiation also has beneficial effects on plants. They include improved germination, accelerated growth rate and development, earlier and longer flowering, better root induction from stems and increased harvests.[1]

Cost estimates for the remediation of hazardous waste sites are astronomical.[3] It could take a trillion dollars or more to remediate all the sites in the US. The cleanup cost at one specific site for avoiding each cancer case, assuming that all radiation is hazardous, is estimated to exceed $15 million!

In light of the beneficial properties (or at least harmless properties) of low-level nuclear waste and the high costs of remediation, it seems eminently wise to immediately defer low-level remediation pending reanalysis of the appropriate treatment of benign low-level waste, and, of course, confirmation of how benign that waste truly is.

References

1. See, for example, T. D. Luckey, Health Phys. **43**, 771 (1982); and T. D. Luckey, *Hormesis with Ionizing Radiation*, CRC Press, Boca Raton, Fla. (1980).
2. J. Muckerheide, Am. Nucl. Soc. News, vol. 12, no. 10 (1994).
3. P. H. Abelson, Science **255**, 901 (1992).

JOSEPH J. DEVANEY
Los Alamos, New Mexico

The disposal of radioactive waste is difficult to do safely. We would like to dispose of it so that it remains inaccessible to terrorists or mistakes, cannot leak due to groundwater movement or earthquakes and will stay put for millennia, independent of future political shifts. And at reasonable cost.

So why not put the radioactive waste in strong, heavy drums and just drop them into Earth's own disposal sites—subduction trenches. (The Aleutian Trench is within US territorial waters.) They will immediately sink through 5 kilometers of water. Heavy drums will sink into the ooze on the bottom; hot, heavy drums will continue to sink, deep into the thick sediment accumulating in the subduction trench. Those buried, unmarked and scattered drums under deep water would be immune to recovery by the US government, never mind terrorists. The radioactivity will be deep under accumulating cold mud, so any leakage will not contaminate the ocean. And as the millennia go by, the material will be subducted down hundreds of kilometers, not to be seen again for an eon. Even if the water in the mud came up in a volcano after a million years, long-decay radioactives are not volatile.

This solution would be permanent, immediately available with simple technology, cheap and a lot safer than "managing" nuclear waste. For Earth's sake, let's act now. And while we're about it, let's get the Russians to scuttle their rotting nuclear submarines in the Kuril Trench, rather than in shallow water next to shore.

JACK NEWMAN
Lindisfarne, Tasmania, Australia

AHEARNE REPLIES: I and the other writers involved in the special issue on radioactive waste appreciate the interest shown by the letter writers. As the guest editor of that issue, I have coordinated the preparation of the following collective response.

With regard to John Tanner's remarks, Bill Kastenberg and Luca Gratton note that, to the best of their knowledge, no society has ever considered or attempted an institutional undertaking that demands system reliability over a huge time interval such as that proposed for the permanent geologic disposal of radioactive wastes. This makes the Yucca Mountain project the first of its kind and prompts legitimate concerns on the part of the nuclear waste management community regarding the potential hazards posed to future generations. There are uncertainties in our knowledge about how the proposed repository system would interact at future times with the geology and hydrology of Yucca Mountain. Therefore, Tanner's assertion that the nuclear waste dumps "will not ever cause a problem" requires substantiation that currently cannot be offered, although some uncertainties are being reduced. Recent evidence regarding percolation fluxes, colloidal transport of the actinides and the degree of matrix liquid imbibition under nonequilibrium fracture flow conditions (to name a few) have forced revisions of previous estimates of the hydrological and geochemical environment at Yucca Mountain. It is necessary to consider waste migration ten thousand to one million years hence because the best contemporary analytic tools predict that that distant period will be when peak concentrations of radionuclides may be found in the groundwater outside of the defined repository facility. This prediction motivated the National Academy of Sciences to endorse a longer regulatory period. Additionally, if failures of the repository system occur prematurely, robust design offers some assurance that the system will fail gracefully and still satisfy the regulatory safety requirements. By attempting to ensure safety for millennia, the repository designers hope to prevent setting up some distant future generations for disaster.

Kevin Crowley agrees with Ludwig Kowalski's comment that transmutation is of interest. However, space limitations in the special issue prevented Crowley from offering more than a short mention of the subject, and he believed it best to concentrate on the technical issues rather than research projects. Kowalski focuses his attention on transmutation but does not mention R&D on separations. A good overview of transmutation and separation technologies can be found in the 1995 National Research Council report cited in Crowley's article (see reference 14).

With respect to the issue of spent fuel costs raised by Frank Rahn, Warner North notes that the cost of maintaining a fuel pool is treated as a part of the operating cost of a nuclear power plant as long as the plant is operational. When the plant is no longer used for electricity generation, the cost of maintaining the fuel pool is allocated to spent fuel storage. Although dry cask storage may provide a less costly interim storage alternative, the owner of a decommissioned nuclear plant would clearly prefer to close down its fuel pool and any dry cask storage facilities and to have the Department of Energy take possession of the spent fuel. Any decision to merely inject waste at the Nevada Test Site, as Rahn suggests, could be expected to face major environmental challenges, as well as engineering concerns about retrieving the waste if problems arise.

Joseph Devaney raises the radiation hormesis issue, as well as the question of the linear no-threshold assumption used for low levels of radiation exposure. Committees of the Nuclear Regulatory Commission and the National Council on Radiation Protection and Measurement (NCRP) currently are reexamining that assumption. The other issue that Devaney points to is that there is no standard for what constitutes an acceptable level of cleanup at DOE sites. It is an extremely important issue, and one that has been raised in many reviews, but it can be resolved only by significantly involving those likely to be most affected by any such criterion, the local people. Such a collaborative effort could lead to agreement on lower cost solutions, including less-than-pristine final conditions, as has been demonstrated successfully at the Fernald DOE site in Ohio.

Finally, Jack Newman brings up deep-seabed disposal, an option often raised in the waste disposal discussion. It is a method currently banned by international treaty, and any consideration of the option has been blocked in recent years by the environmental risks associated with it. However, in any serious reevaluation of disposal of high-level waste, deep-seabed disposal should be examined as a possible international solution.

JOHN F. AHEARNE
(ahearne@sigmaxi.org)
Sigma Xi Center
Research Triangle Park, North Carolina

PS: Nuclear Waste Terms Redefined

On page 23 of your June 1997 issue, there are errors in four of the five definitions given for units of measurement in the box entitled "Glossary of Terms Regarding Nuclear Waste":

The curie is not "the amount of radiation emitted from one gram of radium-226"—a misinterpretation arising from early definitions of this unit. True, it was once defined as the number of disintegrations per second occurring in 1 g of radium-226. However, the value of the curie defined in this way changed as the accuracy of measuring decay rates improved, and the curie is now defined as the activity of any radionuclide in which the number of nuclear transformations per second is exactly 37 billion.

The rad is not "equal to the amount of radiation that deposits 0.01 J kg^{-1}"—that is, it does not define an amount of radiation. Rather, 1 rad is equal to an absorbed dose of 0.01 J kg^{-1} deposited in any material by any kind of ionizing radiation.

The rem is not "a unit of equivalent dose of ionizing radiation that has the same effect on biological tissue as one roentgen of high-energy x rays. . . ." Rather, it is a unit of equivalent dose that equals the dose in rads multiplied by appropriate weighting factors to account for the dependence of biological effects on the type of ionizing radiation, the dose