SCIENCE FOR DEMOCRATIC ACTION

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WANTED: Sound Radioactive Waste Management Policy

Chemists and chemical engineers were not interested in dealing with waste. It was not glamorous; there were no careers; it was messy; nobody got brownie points for caring about nuclear waste... The central point is that there was no real interest or profit in dealing with the back end of the fuel cycle.

—Carroll Wilson, first general manager of the Atomic Energy Commission, 1979[1]

The first high-level radioactive wastes were produced during World War II as a result of plutonium production during the Manhattan Project. These wastes were placed in temporary storage tanks with little thought as to how they would be managed or disposed of in the long-term. That approach may have been understandable as part of the exigencies of war. But in the decades that followed, the same relative neglect of nuclear waste management persisted. Today, after dozens of studies and tremendous expense, waste management continues to be poor, and long-lived radioactive wastes from military and commercial activities continue to pose serious safety, health, and environmental risks.

In 1992 IEER published a study analyzing the management of long-lived radioactive wastes.[2] Five years later, our conclusions remain essentially the same. This newsletter reviews and updates our earlier findings on nuclear waste management policy, and, in light of proposed policy changes, offers suggestions for an alternative approach.

The Needless Yucca Mountain Rush of 1998

BY ARJUN MAKHIJANI

Spent fuel from nuclear power plants, which contains over 95 percent of the radioactivity in the entire nuclear waste inventory (see center-fold table), will remain dangerous for millions of years. It is estimated that peak doses from land-based repositories will occur a hundred thousand years or more into the future.

PHOTO COURTESY OF VIRGINIA POWER

Dry cask storage at The Surry Power Station in Newport News, Virginia, 1992. An NAC-28 storage container is being put into place. The other containers are GNSi Castor V-21 containers.

At the present time, most of this waste, in the form of ceramic pellets encapsulated in zirconium alloy fuel rods, is stored in large enclosed pools at nuclear power plants. After the waste has cooled for some years, it can be moved to dry casks. This is how some waste is currently stored. The Nuclear Regulatory Commission has declared dry cask storage to be safe for up to a 100-year period. Given the inherently dangerous nature of spent nuclear fuel, such a claim must surely be regarded as relative. But currently, there is no other approach to interim management of nuclear waste that presents environmental or safety advantages over on-site storage.[3] So why are the proponents of a repository and/or a centralized storage site at Yucca Mountain[4] in such a rush to move the waste?

See **Needless Rush**, *page 2*

(endnotes on page 7)

Needless Rush, *from page 1*

The answer lies in the artificial deadline created by the Nuclear Waste Policy Act of 1982. This "inside-the-beltway" compromise between the nuclear industry (including nuclear utilities), the Department of Energy (DOE), and arms control advocates mandated that a repository for spent fuel and highly radioactive reprocessing wastes from military plutonium production be opened by 1998. One of nine western and southwestern sites already under investigation by the DOE was to be selected.[5] This schedule was decades faster than the repository program of any other country. The following factors heavily influenced the 1982 deal:

Poor DOE performance and utility desires to get rid of the waste have created an artificial urgency.

1. The potential for use of commercial plutonium as a fuel was declining because of its high cost relative to uranium, and it was also posing an increasing proliferation liability. Spent fuel contains about 1 percent plutonium that can be extracted for use as a reactor fuel. Separated plutonium can also be used to make nuclear weapons. Early spent fuel disposal seemed an economically advantageous way for nuclear utilities to get rid of a growing environmental liability.

2. Nuclear power plant manufacturers felt that they could sell more plants if they could point to a "solution" to the problem of spent fuel management. The rush of the nuclear power plant manufacturers was partly motivated by a 1978 California decision not to allow more nuclear plants to be built in the state until there was a clear solution to the problem of nuclear waste, insofar as this waste represented an economic liability for utilities.

3. Arms control advocates and others felt that a quick opening of a repository would make permanent the no-commercial-reprocessing policy of the Carter administration, which was threatened by the Reagan administration's stated desire to reverse it.

After political pressures eliminated all other potential sites, the DOE was directed by Congress to investigate Yucca Mountain in Nevada. (See "The Road to Yucca Mountain," p. 14.) However, the geology of the site is not well suited for high-level waste disposal, and the land is claimed by the Western Shoshone people. Further, while the site is still undergoing studies to determine its suitability as a repository, on numerous occasions standards have been made more lax in order to accommodate its deficiencies (see editorial). Should it be declared suitable, the earliest opening for a Yucca Mountain repository is the year 2010.

Another part of the 1982 deal was a commitment by the DOE to take charge of the spent fuel from the utilities by 1998. In 1996, a US Circuit Court of Appeals agreed with many utilities and states that DOE's contracts with utilities are binding and that DOE will be liable for damages arising from breach of contract if it does not take charge of the fuel at that time.

Since the passage of the act, the DOE has bungled its repository site selection process, both politically and scientifically. In so doing, it has wasted a good deal of the nuclear utilities' ratepayers' money, who, under the 1982 law, are financing the site selection process by a charge on electricity rates. The poor DOE performance and utility desires to get rid of the waste as early as possible have combined to create an artificial urgency that is unrelated to the technical issues at hand.

See **Needless Rush**, *page 6*

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6935 Laurel Avenue
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Phone: (301) 270-5500
FAX: (301) 270-3029
E-mail: ieer@ieer.org
Web address: http://www.ieer.org

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GUEST EDITORIAL

The Yucca Mountain Standard: Proposals for Leniency

BY THOMAS H. PIGFORD

The proposed dump at Yucca Mountain, Nevada, for spent nuclear fuel and other highly radioactive waste needs an official standard to protect the public from release of radioactivity. Proposed legislation would have Congress writing the official standard for protecting public health from releases of radioactivity at Yucca Mountain.

Whether the standard should be written by Congress or by the Environmental Protection Agency, it must be stringent enough to build confidence in the adequacy of public health protection in the face of legal and political challenges. In these times of budgetary shortages and slow progress in waste disposal, pressures are being exerted both on Congress and scientists for more lenient standards. In my opinion this relaxation of standards is unwise and unnecessary.

The argument over safety standards centers on five key issues:

1. For how long must protection be assured?

Protection must be assured for the far distant future, as long as slow continued leakage of radioactivity can contaminate ground water. It is scientifically feasible to calculate radiation exposure to people who use that ground water hundreds of millennia from now (though the uncertainty of the calculations increases as the time period becomes longer). The annual radiation dose to a person living 100,000 years from now is estimated to be about 10 million times greater than that to a person during the first 10,000 years. The present scientific consensus requires such long-term calculations for evaluating future exposures and risks. Proposals within Congress and by industry and the Department of Energy would terminate calculations at 10,000 years, long before significant exposures occur. There is no scientific basis for such an enormous relaxation of health protection.

2. Who is to be protected?

To protect all future people, radiation doses to individuals who receive maximum exposure must be less than the safe and allowable doses. It is international consensus that these maximally exposed people will be subsistence farmers who draw water from wells near the waste dump, grow most of the food they eat, and live in the era of maximum releases. All other people will receive lower doses. Some congressional proposals have rejected that traditional conservative standard in favor of calculating radiation doses averaged over the general population in the vicinity. Such "population dilution" produces calculations a hundred or so times lower than those produced from the traditional approach. Protecting the "average individual" would provide no assurance that all individuals will be protected. Legislation passed by the Senate included wording that can be interpreted as specifying that future wells producing contaminated water would be no closer than present wells, about 30 miles away from the Yucca Mountain Site. This would also be a considerable relaxation in health protection.

3. How much radiation exposure is allowable?

Maximum doses to the public now allowed for licensed nuclear facilities are typically 5 to 25 millirems per year to *maximally exposed individuals*. Corresponding annual doses averaged over populations in the general vicinity of such facilities would be much less, typically a few hundredths of a millirem. Various proposals to relax the standard have been made by the nuclear industry, the National Research Council and by Congress. One proposal would permit releases that give population-average doses as high as 100 millirems per year, an enormously permissive departure from present regulatory practice in the U.S. and abroad. The Senate bill would allow about 30 millirems using a needlessly permissive rule recommended by the National Research Council (see below).

4. Can future people be excluded from the site area?

Current proposals before Congress designate the Yucca Mountain site area extending far beyond the repository itself to be controlled as an exclusion area. Future people would be prohibited from living or drawing water from within the site area. However, there is no basis for assuming that institutions can be relied on to enforce such exclusion for tens to hundreds of millennia. Ignoring the higher doses that can be received by future individuals who could use water from nearby wells is an unwarranted relaxation of protection.

5. Can habits of future people be predicted?

Because we cannot predict the character and habits of people who will live tens and hundreds of millennia from now, Congress (or whoever sets the standard) needs to address how future radiation doses are to be calculated. International consensus makes the conservative assumption that some future people will use contaminated ground water to grow most of their lifetime intake of food. Doses to these maximally exposed individuals

See **Editorial**, *page 5*

Transmutation: Not a Repository Alternative

BY ARJUN MAKHIJANI

In 1996, the National Research Council of the U.S. National Academy of Sciences published a detailed report on radioactive waste management entitled: *Nuclear Wastes: Technologies for Separations and Transmutation*.[1] The purpose of this report was to examine existing and new technologies for separating long-lived radionuclides, such as plutonium-239 and iodine-129, from spent nuclear reactor fuel and high-level reprocessing wastes and transmuting them in various kinds of nuclear reactors into shorter-lived radionuclides.

Spent nuclear reactor fuel for the most common reactor (the light water reactor) typically contains about 94 percent uranium, five percent highly radioactive fission products (a few of which are very long-lived), just under one percent plutonium, and small proportions of other transuranic elements such as neptunium and americium.

Long-lived fission products, such as iodine-129 and long-lived heavy elements such as plutonium-239 can be converted into short-lived radionuclides by bombarding them with neutrons in various kinds of nuclear reactors. This process is called transmutation. (Note: Transmutation by fission is responsible for the generation of nuclear energy in the first place.) Proponents claim that transmutation might enable a high-level waste management program to avoid the construction of a geologic repository.

In order to use nuclear reactors (whether existing varieties or new kinds) to transmute long-lived radionuclides into short-lived ones, it is first necessary to separate out the long-lived radionuclides. Hence, successful waste management by this approach requires both separation technologies and transmutation technologies. The report considers both technological and economic aspects of these technologies.

The National Research Council study was partly motivated by the need for an independent evaluation of claims made by the US Department of Energy and its contractors, General Electric and Argonne National Laboratory, that the advanced liquid metal reactor and the associated reprocessing technology, called electrometallurgical processing, could drastically reduce the amount of long-lived radioactive waste needing management and disposal. The study examines whether any combination of separation and transmutation technologies could result in the conversion of sufficient amounts of (essentially all?) long-lived radionuclides into relatively short-lived radionuclides that can be stored until they have decayed to very low levels of radioactivity. The study concluded that current technologies could not accomplish this purpose because sufficient amounts of long-lived radionuclides would remain in all cases to require the construction of a repository. Moreover, it would take hundreds of years to reduce the

See **Transmutation**, *page 5*

Transmutation, *from page 4*

radioactivity of transuranics by a factor of ten, and thousands of years to reduce it by a factor of one hundred.

Technologies still under development, such as a sub-critical reactor connected to an accelerator neutron source, proposed by Los Alamos National Laboratory,[2] would take a long time to develop and it remains speculative whether they could be commercialized. Even if they were, it is "improbable" that the very high degree of separation necessary to guarantee transmutation of essentially all long-lived radionuclides could be achieved.

The study provides up-to-date cost estimates for building and operating a new reprocessing plant in the United States, based on European experience. The study states that reprocessing costs for actual plants (THORP in Britain and UP3 in France) are reported to be $600 to $1,400 per kilogram of heavy metal.

Costs of a new US reprocessing plant would depend on whether the plant is government owned, utility owned, or commercial (see Table 5). These costs would be different because governments would have the lowest costs of capital, no taxes, no insurance requirements, and no requirements for profit, while at the other extreme, a purely private company would have the highest charges in all these categories. Utilities, which are regulated monopolies, would have costs between those of government and private industry in most of these areas.

TABLE 5. Estimated Reprocessing Costs
(in 1992 constant dollars)[3]

Operator	Unit Cost, $/kg of heavy metal	Cost cents/kWhe, (rounded)
Government	810	0.25
Utility	1,330	0.42
Private	2,110	0.67

kWhe = kilowatt-hour, electrical

These costs apply to reprocessing the spent fuel that results from an initial loading of fresh uranium fuel. If the reactor is fueled with recycled uranium or plutonium then the costs of reprocessing would be higher. The processes that would need to be added to reduce process losses of radioactive materials to very low levels would add further costs.

Finally, the study rejects the claim by Argonne National Laboratory that electrometallurgical processing costs would be about $350 per kilogram of heavy metal, or only about one-sixth the private facility costs of a PUREX plant. Past experience indicates that initial cost estimates are likely to grow

See **Transmutation**, *page 20*

Editorial, *from page 3*

are compared with the safe and allowable level. Congress should avoid a more lenient proposal in a National Research Council report that would attempt to estimate location, occupancy, and living habits of future people.[1] Less than lifetime occupancy by subsistence farmers would reduce calculated radiation doses and allow much greater release of radioactivity to the environment. There is no scientific basis for predicting where future people will live and how much of their lifetime consumption of food and water will be contaminated, yet the National Research Council proposes to make such predictions in the guise of policy. Some occupancy factors, hypothesized but without scientific basis, would allow releases of radioactivity to the environment several thousand times greater than now allowed for waste-disposal projects. The National Research Council has failed to recognize the serious fallacies in its proposal and its many scientific errors that would introduce further relaxation of protection and safety.

On each of these issues, I believe the traditional, conservative, scientifically based alternative is the proper, prudent, and economical one. If any standard is to be relaxed, then we should require that scientific fact and logic support the change. At the present time, no scientific bases exist to support a policy less stringent than the traditional subsistence-farmer approach in effect today. Congress must reject pressures for short-term expediency and economy lest, by enacting policy that compromises scientific validity and credibility, it undermines public confidence and puts an end to all further nuclear development and research.

The scientific community and the public will find it difficult to understand why Congress would adopt a standard that is less safe in protecting public health than the traditional approach—the approach that has been adopted for all geologic disposal projects in other countries and in the United States.

Thomas H. Pigford is a professor of nuclear engineering at the University of California in Berkeley, California.

[1] See: Committee on Technical Bases for Yucca Mountain Standards, *Technical Bases for Yucca Mountain Standards*, (Washington: National Academy Press, 1995); and SDA Vol. 4 No. 4.

Needless Rush, *from page 2*

Of the three reasons for the 1998 deadline for a repository, two are clearly associated with narrow special interests. The third has been made moot by events. We will examine each more closely.

Utility Interest in Reducing Liabilities

Shifting the liability of spent fuel from utilities to the DOE is not going to reduce nuclear dangers posed by spent fuel. In fact, given the influence of those who favor reprocessing in the DOE, transferring spent fuel to the DOE only increases the chances that nuclear industry lobbyists will be able to persuade the US government to consider reprocessing spent nuclear fuel. Reprocessing will not only aggravate proliferation risks, but will also increase the problems of waste management (see SDA Vol. 5 No.1 on reprocessing). Legislation considered (but not enacted) in 1996, had, for the first time in a decade-and-a-half, provisions reconsidering reprocessing as a method of spent fuel management. Interestingly, 1996 was also the year in which a committee of the National Research Council of the National Academy of Sciences found that reprocessing was a poor way to address waste management issues (see Transmutation article, p. 4).

Since 1982, nuclear utilities have been charging their ratepayers a fee which they then pass on to the federal government's Nuclear Waste Fund. Utilities and the state regulatory commissions are right to be aggravated that despite the large sums paid into this fund, the DOE does not yet have a viable waste repository program. Perhaps this is reason enough to use the fund to cover the utilities' costs for extended on-site storage (provided the utilities agree to a restructured and sound repository program).

In insisting that DOE take charge of this fuel next year, utilities are only behaving like intransigent NIMBYs. This attitude was epitomized by a utility executive in a DOE-sponsored public meeting in 1991 when he said that the government should take charge of the spent fuel and that "I don't care where you put it"—hardly a sentiment conducive to a sound repository program. Real solutions will require a far more thoughtful approach.

The nuclear industry is asking for private liabilities to be transferred onto the shoulders of government, and hence onto ratepayers and taxpayers.

The Futile Hope of New Nuclear Power Plants

Wall Street has rejected nuclear power quite independently of the nuclear waste issue. There are no US utilities lined up to order new power plants should the DOE take charge of commercial spent fuel. Indeed, some nuclear power plants are closing prematurely due to unexpectedly high operating and maintenance costs. Moreover, by urging the government to take charge of this liability before a scientifically sound long-term management program has been put into place, the nuclear industry is simply asking for private liabilities to be transferred onto the shoulders of government, and hence onto ratepayers and taxpayers. (It is not at all clear that the Nuclear Waste Fund will provide sufficient funds for a sound repository program.)

Non-Proliferation Goals

The Reagan administration was singularly unsuccessful in interesting US private industry in reprocessing. While economic problems and proliferation risks stopped reprocessing in the US, global commercial reprocessing has grown considerably since the early 1980s, especially in France and Britain, where it is essentially operating on taxpayer and ratepayer subsidies. Thus, despite the US policy of no commercial reprocessing, global stocks of separated weapons-usable plutonium have been growing. This is increasing nuclear dangers around the world. But the US is doing little or nothing to stop this commercial reprocessing, even refusing to use its leverage, for instance, on Japanese contracts with French and British reprocessing companies.

The global inventory of separated commercial plutonium is increasing rapidly and it will soon exceed all military plutonium.[6] Plutonium reprocessing also continues in Russia. Thus, the most effective strategy for stopping reprocessing and the proliferation dangers arising from it would not be aimed at US spent fuel management, but at the policies of other countries. Hence, the urgency argument as it relates to proliferation has become irrelevant.

Finally, the US schedule for opening a repository by 2010 is still far faster than any other country, and no significant non-proliferation goal is being accomplished by adopting this breakneck pace. The rush to open a repository not only fails to achieve any significant non-proliferation goal, but has also led to selection of a technically flawed site that could result in unacceptably high doses to future generations. This haste buys society nothing, but instead jeopardizes a great deal in terms of protecting the health of future generations.

It is true that the delays in the repository program together with legal challenges to the DOE to take charge of the waste have created pressures for examining reprocessing again in the US. However, the need

See **Needless Rush**, *page 7*

Needless Rush, *from page 6*

to fend off an unwise policy on reprocessing cannot and should not be reason to settle for a repository program that is fundamentally flawed.

The Unreasonable Rush

The arguments for a centralized Monitored Retrievable Storage (or MRS) are even more parochial than those for a repository. Transporting waste to a central storage site well before a repository is due to open incurs needless risks. Many of the radionuclides that pose serious risks in waste transportation have half-lives of about 30 years or less. Extended on-site storage would allow time for development of a sound repository program. It would also greatly reduce the consequences of any transportation accidents, because some of the most dangerous radionuclides would undergo considerable decay during the storage time.

Nuclear utilities should not promote a flawed repository program or perpetuate an injustice on the Western Shoshones.

That time can also be used to develop transportation casks that would be more resistant to accidents, and to provide adequate emergency training and equipment to fire and police departments of communities along transportation routes. All of these goals are compromised by a rush to build an MRS facility, as are nonproliferation goals: if a large portion of spent fuel is consolidated at one site, the pressure for and risk of reprocessing is likely to increase.

MRS and repository proponents argue that storage at one centralized site is far safer than storage at dozens of reactor sites. This argument has been presented without any serious analysis. No assessment has been done comparing the risk of transporting relatively fresh fuel aged only a few years to transporting spent fuel when cesium-137 and strontium-90 have substantially decayed. No account has been taken of the risk of transporting the waste again should Yucca Mountain be found to be an unlicensable site. Moreover, it is quite mysterious that the proponents of nuclear power should at once argue that reactors are safe and secure, and at the same time claim that on-site storage of spent fuel is somehow so risky that a vast program to transport it to a centralized location must be undertaken before a reasonable repository program is in place. Finally, no coherent argument has been presented for why the DOE can be trusted to be a good environmental steward of this waste when its environmental record in other areas is, shall we say, undistinguished. Or does the nuclear industry mean to imply that its stewardship of things nuclear is inferior to that of the DOE?

The sense of urgency that the nuclear industry has created around the issue of spent fuel management is an artificial construct of its narrow legal and political battles with the government. Utilities that own nuclear power plants are right in asking the federal government to take responsibility for spent fuel because the government made a commitment to do so, and because leaving waste containing so much plutonium in private hands for the indefinite future represents an unacceptable security problem.[7] But a federal guarantee to take the waste should not extend to new power plants. And it is patently unjust that nuclear utilities should use arguments regarding liability for waste to further a demonstrably flawed repository program, to perpetuate an injustice upon the Western Shoshone people, or to impose needless risks on the public along transportation routes to an unnecessary centralized storage site.

1 C.L. Wilson, "Nuclear Energy: What Went Wrong" *Bulletin of the Atomic Scientists*, June 1979, p. 15.

2 See A. Makhijani and S. Saleska, *High-Level Dollars, Low-Level Sense*, (New York: Apex Press, 1992).

3 By the term "on-site storage" we mean storage at the reactor site or, in some cases where this may not be prudent (relatively speaking) for periods of several decades, storage as close to the reactor site as is compatible with safety.

4 The proposed Yucca Mountain repository is located in southern Nevada, about 100 miles northwest of Las Vegas on the edge of the Nevada Test Site.

5 A second repository chosen from among eastern sites was supposed to be opened at a later date, but the DOE abandoned the search for this second repository in 1986. See "The Road to Yucca Mountain," p. 14.

6 At the end of 1995, the global inventory of separated commercial plutonium was 195 metric tons, and separated military plutonium stood at 270 metric tons. Worldwide, about 20 metric tons of plutonium are being separated from commercial spent fuel each year. See *Energy & Security* (IEER's global newsletter) Issue No. 1, 1996, p. 5. This newsletter is also available on IEER's website, www.ieer.org. To order a free subscription to *Energy & Security*, contact IEER.

7 It is also noteworthy in this context that nuclear power is more a creature of Cold War competition than sound economics, so that the government does bear the responsibility for spent fuel from existing power plants. See IEER's report, *The Nuclear Power Deception*. Ordering information is on page 4.

NUCLEAR NEWS

Citizens Against Nuclear Trash (CANT) has won round two of its battle against a proposed uranium enrichment plant in Louisiana. In early May, the Nuclear Regulatory Commission (NRC) denied the license application of Louisiana Energy Services (LES) on the grounds that there was evidence that the site selection process was affected by "racial considerations." LES can appeal the decision. The evidence was provided by Professor Robert Bullard, the expert retained by CANT. Lawyers in this case were Diane Curran and Nathalie Walker of Sierra Club Legal Defense Fund. IEER also provided technical assistance in the case.

AN EXTENDED CENTERFOLD FOR TECHNO-WEENIES

Radioactive Waste: The Regulatory Mess

COMPILED BY PAT ORTMEYER

Hundreds of millions of cubic meters[1] of radioactive wastes, including spent fuel from nuclear power plants, waste from nuclear weapons production, contaminated soils, mine and mill tailings and other wastes, contaminate commercial and military sites across the country. (See bar chart of waste volumes on page 15.) This extended centerfold will discuss IEER's findings on the current policy for the management of these wastes, based on our 1992 study, *High-Level Dollars, Low-Level Sense.*[2] Our analysis includes four key findings:

1. Radioactive waste is inappropriately defined.

Classification of radioactive wastes in the United States is fundamentally flawed in that waste categories are based on the origin of the waste, not on the physical or chemical properties that determine the hazards of the waste, and hence its safe and proper management. For example, "high-level waste" is defined as irradiated fuel from commercial nuclear power plants, or waste resulting from reprocessing.[3] "Low-level waste" is a catch-all category, defined as any waste that is not high-level waste, transuranic waste, or uranium mill tailings. A summary of the current waste classification system and accompanying regulatory status is shown in Table 3.

A major problem of this classification system is that it does not systematically take into account actual radioactivity levels of waste either overall or per unit volume. Thus, so-called "low-level waste" can contain materials more radioactive than those classified as "high-level waste." For example, the radioactivity in the most radioactive portion of commercial low-level wastes—300 curies per cubic foot[4] is actually three times more radioactive than the average radioactivity in high-level wastes from nuclear weapons production activities (see Table 1).

This skewed classification system poses serious problems for waste management and disposal. "Low-level" waste is routinely disposed of by putting it in wooden boxes or 55-gallon drums and burying it in shallow trenches. Cardboard boxes have also been used. As a result, some wastes which are significantly more radioactive than high-level or transuranic wastes (which are slated for deep geologic burial) are disposed of in shallow pits. Another problem is that waste classification is determined without reference to the longevity of the radionuclides in the waste. Both high- and low-level wastes can contain short- and long-lived radionuclides.

Although transuranic (or TRU) wastes are not classified by their source, there are problems with how they are categorized and managed. TRU wastes are essentially those resulting from plutonium production and processing, namely for weapons

See **Centerfold**, *page 9*

TABLE 1. Low-Level Waste Characteristics
(compared to selected samples)

	Avg. Concentration (curies/ft³)	Selected Samples (curies/ft³)
Low-Level Waste		
Class A	0.1	
Class B	2	4.4 (NY Cintichem facil.)
Class C	7	160 (NY reactor avg.)[1]
Greater-than-C	300 to 2,500[2]	
Transuranic Waste		
Contact-handled	0.57	
Remote-handled	47	
Military High-Level Waste	100	920 (Savannah River sludge) 3.7 (Hanford salt cake) 7,110 (Savannah River Glass, projected)
Commercial Spent Fuel	73,650[3]	

Source: A. Makhijani and S. Saleska, *High-Level Dollars, Low-Level Sense*, (Takoma Park, MD: IEER, 1992), p. 26.

1 Average Class C wastes from New York State's nuclear reactors.

2 The 300 figure is based on the 1985 inventory. The higher figure represents anticipated inventory in 2020, including some decommissioning wastes.

3 Based on average activity in all spent fuel at the end of 1989 and on overall fuel assembly dimensions.

TABLE 2. NRC Limits Defining Class A, B, and C Low-level Waste
(curies per cubic meter)

A. "Long-lived radionuclides"	Half-life (years)	Class A	Class B	Class C
Carbon-14	5,700	0.8	N/A	8.0
Carbon-14 in activated metal	5,700	8.0	N/A	80.0
Nickel-59 in activated metal	75,000	22.0	N/A	220.0
Niobium-94 in activated metal	30,300	0.02	N/A	0.2
Technetium-99	213,000	0.3	N/A	3.0
Iodine-129	15.7 million	0.008	N/A	0.08
Alpha-emitting transuranics with half-lives greater than 5 years	–	10.0*	N/A	100*
Plutonium-241	14	350.0*	N/A	3,500*
Curium-242	163 days	2,000*	N/A	20,000*
B. "Short-lived radionuclides"				
Tritium	12.3	40	no limit**	no limit**
Cobalt-60	5.3	700	no limit**	no limit**
Nickel-63	100.1	3.5	70	700
Nickel-63 in activated metal	100.1	35	700	7,000
Strontium-90	28.5	0.04	150	7,000
Cesium-137	30	1	44	4,600
Total of all nuclides with less than 5-yr. half-life	–	700	no limit**	no limit**

Source: NRC 1988 (10 CFR Part 61.55).

* Units are nanocuries per gram. (Note that Pu-241 and Cm-242 have long-lived decay products. Quantities given decay to approximately 100 nanocuries per gram of Am-241 and Pu-238, respectively.)

** There are no limits established for these elements in Class B or C wastes. If waste is contaminated with these radionuclides in concentrations greater than their Class A limits, the waste is Class B, unless the concentrations of other radionuclides determine the waste to be Class C or above, independent of these nuclides.

Centerfold, *from page 8*

purposes. The box on page 12 discusses some of the confusing and illogical regulations that currently govern TRU waste management.

2. Existing regulations and plans for long-lived radioactive waste management and disposal are irrational and incoherent.

Regulations for disposal of long-lived radioactive wastes are internally inconsistent and scientifically unsound, raising serious doubts about their ability to adequately protect public health and the environment.

Currently, Nuclear Regulatory Commission (NRC) regulations for Class A and B wastes (see Table 3) require institutional controls at low-level waste disposal facilities for up to 100 years because, according to the NRC, after this time, these wastes will have decayed to levels that would pose an "acceptable hazard" to an intruder. But even many of the so-called "short-lived" wastes in these classes are allowed in concentrations that will not have decayed to NRC-defined acceptable levels after this 100-year period.

For example, as shown in the Table 2, wastes contaminated with nickel-63 in concentrations up to 70 curies per cubic meter can be buried as Class B waste. At this concentration, after 100 years (the half-life of nickel-63) this waste will have decayed to 35 curies per cubic meter—10 times higher than the Class A concentration limit of 3.5 curies per cubic meter. If this waste were to be retrieved from the disposal site and reburied, it would still be classified as Class B waste, requiring the 100-year

See **Centerfold**, *page 12*

TABLE 3. Regulatory Status of Waste Generated in the US Nuclear Fuel Cycle
(Commercial and Military)

. . . and you thought the tax system was complex!

<table>
<tr><th>TYPE OF WASTE</th><th>CHARACTERISTICS</th><th>REGULATORY STATUS</th><th>COMMENTS</th><th>VOLUME (cubic meters)</th><th>RADIOACTIVITY (million curies)</th></tr>
<tr><td colspan="6">HIGH-LEVEL WASTE</td></tr>
<tr><td>Spent Nuclear Fuel</td><td>Total weight = 34,600 MTIHM (metric tons of initial heavy metal) as of 12/31/95.</td><td>■ storage: NRC
■ disposal: NRC technical regs.; EPA regs. for all repositories except Yucca Mountain</td><td>Over 95% of all the radioactivity in nuclear waste. (See main article & editorial for info. on proposed Yucca Mtn. regs.)</td><td>14,200</td><td>28,600[1] (no estimate available for DOE spent fuel)</td></tr>
<tr><td>Reprocessing Waste</td><td>Supernate, sludge, "salt cake," and some vitrified waste.</td><td>■ DOE: self-regulation
■ long-term regulations as above</td><td>Almost all from military plutonium separation. About 3% of total radioactivity in nuclear waste.</td><td>373,400</td><td>915.5</td></tr>
<tr><td colspan="6">LOW-LEVEL WASTE</td></tr>
<tr><td>Class A</td><td>Booties, gloves, some medical waste, etc. May contain some long-lived radionuclides.</td><td rowspan="4">■ this classification applies to NRC licensees</td><td rowspan="3">DOE has own classification system; EPA effort to regulate has been abandoned. Shallow land burial allowed. Can contain short-lived and long-lived radionuclides.</td><td rowspan="3">4,980,500</td><td rowspan="3">>20.8</td></tr>
<tr><td>Class B</td><td>Reactor filter resins, etc. Some waste has high radiation levels. May contain some long-lived radionuclides.</td></tr>
<tr><td>Class C</td><td>Irradiated reactor parts, some instruments, etc. Very radioactive.</td></tr>
<tr><td>Greater than Class C</td><td>The most radioactive irradiated reactor parts and some instruments.</td><td>NRC requires repository disposal. But DOE has no repository for it and no active plans to take it.</td><td>(no estimate available)</td><td>(no estimate available)</td></tr>
<tr><td>MIXED LOW-LEVEL WASTE</td><td>Generated mainly from nuclear weapons production; includes organic and inorganic toxics, heavy metals, and radioactive materials.</td><td>■ DOE: Federal Facilities Compliance Act, agreements with states; RCRA
■ NRC licensees: NRC for radioactive portion; RCRA for non-radioactive portion</td><td>Management of toxics can complicate management of radionuclides.</td><td>>151,500</td><td>(no estimate available)</td></tr>
</table>

TRANSURANIC WASTE (TRU waste) includes mixed TRU waste	Exists in many forms and contains many hazardous chemical constituents. Mixed TRU waste generated mainly as part of nuclear weapons production.	■ DOE: self-regulation ■ some EPA regulations apply for mixed TRU ■ EPA standards for TRU repository disposal	Repository slated for New Mexico (Waste Isolation Pilot Plant) but problems confront it, and present plans omit buried TRU waste. (Also see box, p. 12.)	141,000 buried 75,600 stored 216,600 total	>3.38
URANIUM MILL TAILINGS includes 11e(2) material	Large volume; includes radium-226, thorium-230, and toxic heavy metals such as arsenic, molybdenum, vanadium, etc.	UMTRA and DOE self-regulation	200 to 1,000 yr. regulation time far less than 75,000 yr. half-life of thorium-230. Institutional control assumed after 1,000 years.	145,700,000	On the order of 0.3 (radium-226 and thorium-230 combined).
DEPLETED URANIUM	By-product of uranium enrichment; radioactivity levels from alpha radiation similar to TRU waste.	■ not yet formally classified as a waste. DOE considering regs. NRC regulates minor quantities	95.2% of depleted uranium stocks (by weight) are in DUF_6 chemical form	120,000 (DUF_6 only)	>0.2
NORM	Large volume; includes radioactive waste from mining and refining of non-radioactive materials, such as copper; includes many radium-contaminated oil fields.	■ mostly unregulated ■ some state regulations	EPA was considering regulations but effort was abandoned.	Considerable uncertainty about radioactivity and volume of most NORM wastes, as they have never been thoroughly characterized.	
Uranium mine waste	Large volume, comparable to mill tailings; part of NORM wastes.	■ unregulated		Same order of magnitude as mill tailings.	(no estimate available)
DECOMMISSIONING & CLEAN-UP WASTES	Structural components contaminated in varying degrees, contaminated soil, etc.	■ NRC considering regs. ■ DOE has *ad hoc* approach	EPA was considering regulations for DOE but effort was abandoned.	Large volume, and growing	(no estimate available)

Sources: Oak Ridge National Laboratory, *Integrated Data Base Report - 1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics* (Washington: US Department of Energy, DOE/RW-0006, Rev. 11, September 1995), p. 15; and Oak Ridge National Laboratory, *Integrated Data Base Report - 1995* (DOE/RW-0006, Rev. 12, December 1996), p. 13.

DOE:	Department of Energy	NRC:	Nuclear Regulatory Commission
DUF_6:	Depleted Uranium Hexafluoride	RCRA:	Resource Conservation and Recovery Act
EPA:	Environmental Protection Agency	UMTRA:	Uranium Mill Tailings Remediation Act
NORM:	Naturally Occurring Radioactive Materials		

[1] Calculated from US DOE September, 1995 p. 15, table 0.3 and extrapolated to 1996 values based on weight.

[2] Estimates of buried TRU waste volumes are highly uncertain at this time.

Centerfold, *from page 9*

institutional control all over again. Even after more than 400 years, it would only have decayed to Class A concentration levels, at which point NRC regulations would still define it as hazardous for another 100 years.

NRC regulations explicitly acknowledge that some "low-level" wastes will remain hazardous well beyond the time that the institutional and physical controls set forth in its regulations will be effective. The regulations state that:

> consideration must be given to the concentration of long-lived radionuclides. . . whose potential hazard will persist long after such precautions as institutional controls, improved waste form, and deeper disposal have ceased to be effective. These precautions delay the time when long-lived radionuclides could cause exposures.[5]

Thus the NRC admits that the regulatory controls for low-level waste merely push the hazards posed by long-lived radioactive waste into the future, rather than assure that the public and the environment are adequately protected from exposure.

3. The DOE's management of the repository program for long-lived radioactive wastes is exacerbating these problems.

The DOE is responsible for developing geologic repositories for high-level and transuranic wastes. Its high-level waste repository program is at Yucca Mountain, Nevada (see main article), and its transuranic waste disposal project, the Waste Isolation Pilot Plant (WIPP), is located in southeastern New Mexico about 25 miles from the town of Carlsbad. Both of these sites have significant scientific, technical, managerial and environmental problems. Timetables for both programs have slipped repeatedly and costs have escalated.

See **Centerfold**, *page 13*

The Curious Case of Curium-242, Curium-244, and Plutonium-241

BY ARJUN MAKHIJANI

One illustration of the problems in the current waste classification system is the inconsistency between the definition of transuranic waste used by the Nuclear Regulatory Commission (NRC) on one hand, and the Environmental Protection Agency (EPA) and DOE on the other.

The NRC's implicit definition of transuranic (TRU) waste is that which contains alpha-emitting transuranic radionuclides with half-lives greater than 5 years in concentrations greater than 100 nanocuries per gram.[1] It also has separate definitions for two important transuranic radionuclides that do not qualify as TRU waste, but which have decay products that do: plutonium-241 and curium-242.

Plutonium-241 has a half-life of 14.4 years, but its main decay mode is beta, not alpha radiation. However, it decays into americium-241, which is an alpha-emitting radionuclide with a half-life of 432 years, and which does fall into the TRU waste category. Hence the NRC defines waste containing more than 3,500 nanocuries per gram of plutonium-241 as equivalent to TRU waste because it decays into waste containing slightly above 100 nanocuries per gram of americium-241.

Similarly, waste containing more than 20,000 nanocuries per gram of curium-242 (half-life 163 days) decays into waste containing about 100 nanocuries per gram of plutonium-238 (half-life 87 years). Hence, this is also treated as equivalent to TRU waste.

The EPA and DOE definitions of TRU waste, however, include only elements containing alpha-emitting TRU elements with half-lives greater than *twenty* years in concentrations greater than 100 nanocuries per gram. (See Table 4.) The EPA-DOE definition is far less stringent than the NRC definition on several grounds:

- It excludes curium-244, which is an alpha-emitter with an 18-year half-life.[2]
- It does not take into account the fact that high concentrations of plutonium-241 and curium-242 decay into transuranics that meet all EPA-DOE criteria for TRU waste. This means that waste defined as "low-level" by the DOE (because it contains TRU elements with half-lives less than 20 years) could be disposed of in shallow pits. But after several years or decades of storage, some of these wastes could be classified as TRU wastes due to the build up of americium-241 and/or plutonium-238, and hence require deep geologic disposal!

In sum, not only is the TRU waste classification system inconsistent between various bureaucracies, but the contradictions are such that they also imply serious differences in how the same wastes would be managed depending the jurisdiction in which they were created, and the time which is allowed to elapse before disposal.

[1] The NRC defines Greater-Than-Class C (GTCC) waste as that which exceeds low-level waste limits and which must be disposed of in a repository. Therefore, NRC's definition of GTCC waste with only TRU elements should be the same as EPA's TRU waste definition. (EPA requires repository disposal for TRU waste.)

[2] It also excludes another alpha-emitting transuranic, californium-250 (half-life 13 years). This may be an issue with some wastes at Oak Ridge National Laboratory (and elsewhere?).

Centerfold, *from page 12*

WIPP

The geology and hydrology of the WIPP site cause concern about its suitability as a repository for transuranic waste. Water leakage, cracks in the ceilings and floors of waste storage rooms, rockfalls, and the presence of natural oil and gas reserves below the site (which could invite future intrusion) call into question the ability of WIPP to safely contain wastes that will remain hazardous for thousands of centuries.

The 1992 Land Withdrawal Act requires that DOE comply with EPA regulations for permanent disposal of waste. But DOE and its contractors successfully lobbied to water down the requirements of the EPA compliance criteria. DOE's subsequent Compliance Criteria Application was found to be incomplete and the EPA is requesting additional information. Even if WIPP opens, DOE does not plan to use the site to dispose of existing buried TRU waste or transuranic contaminated soil, which together pose the greatest environmental risk and make up the bulk of TRU wastes. (There are hundreds of thousands of cubic meters of buried transuranic waste and transuranic contaminated soil.)

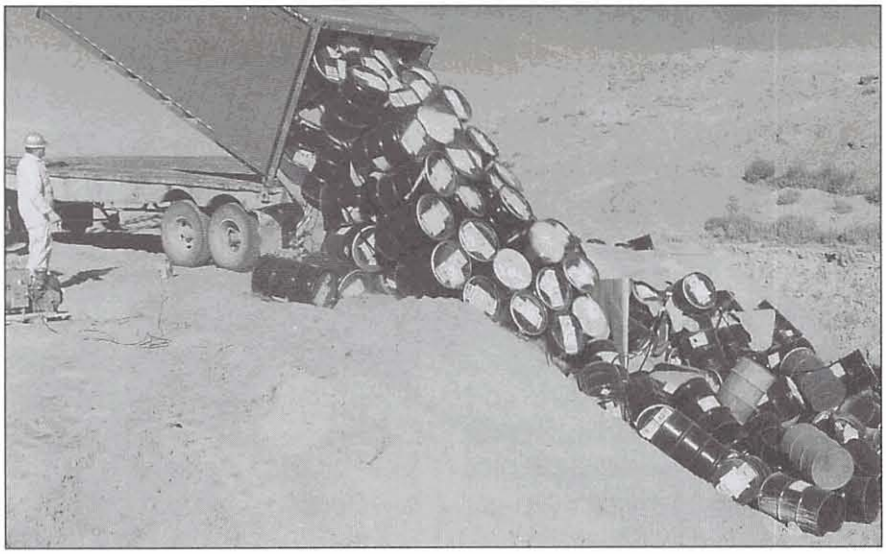


PHOTO COURTESY OF DOE/INEEL

Dump & Cover: Low-level waste disposal at the National Reactor Testing Station (at the Idaho National Engineering & Environmental Laboratory), October, 1969.

The DOE has spent $2 billion on WIPP over the last 20 years, and the project has cost $14 to $15 million per month since the late 1980s, even though no waste has been put in the repository.

Yucca Mountain

Like the WIPP site, the Yucca Mountain site has significant technical problems that may make it undesirable as a high-level waste repository. The site is located on or near 32 active fault lines, including one which intersects the underground storage rooms; it cannot be certified to meet EPA radiation release limits for high-level waste for carbon-14; and there is a potential for volcanic activity in the area. Rainwater percolation into the site is a concern, as is the possibility of the water table itself rising and flooding the repository. Finally, though proponents of the Yucca Mountain repository imply it is a suitable site by describing it as a "remote desert location," the land around the site is used as a source of food and water: Yucca Mountain is located on land claimed by the Western Shoshone people, and there is a farming community 20 miles from the site.

Rather than recognize that the problems with the site may pose

See **Centerfold**, *page 15*

TABLE 4. Waste Classification of Selected Radionuclides by Agency

Radionuclide	Decay Mode	Half Life	Waste Classification: NRC	EPA	DOE
Pu-241 (>3500 nCi/g)	beta	14.4 yrs	TRU	LLW	LLW
decay product: **Am-241** (>100 nCi/g)	alpha	432 yrs.	TRU	TRU	TRU
Cm-242 (>20,000 nCi/g)	alpha	163 days	TRU	LLW	LLW
decay product: **Pu-238** (>100nCi/g)	alpha	87 yrs.	TRU	TRU	TRU
Cm-244	alpha	18 yrs.	TRU	LLW	LLW

nCi/g = nanocuries per gram

Sources: DOE, *Radioactive Waste Management*, DOE Order 5820.2A (Washington: September 26, 1988); Environmental Protection Agency, 1989 (40 CFR 191.18); NRC 1988 (10 CFR Part 61.55).

The Road to Yucca Mountain: A Chronology

1982: The Nuclear Waste Policy Act is enacted. A western site for HLW disposal is to be selected from those DOE was already studying. An eastern site is to be chosen also.

1982–1986: DOE narrows the search for a western site to three places: Hanford, WA; Yucca Mountain, NV; Deaf Smith County, TX. The government controls the land in WA and NV. Critics charge a flawed site ranking process.

1983: A panel of the National Research Council of the National Academy of Scences (NRC-NAS), called the Waste Isolation Systems Panel, issues a comprehensive report, funded by DOE. The report indicates that radiation dose to a maximally-exposed individual from a Yucca Mountain repository could be very high, and that Hanford faces serious geological difficulties due to high rock stresses that cause the rock to fracture. It criticizes proposed EPA standards. DOE and EPA essentially ignore these findings.

1986: DOE publishes its "Draft Area Recommendation Report" specifying dozens of sites for investigation in politically influential eastern and midwestern states. DOE does not list the type of eastern site especially recommended by the 1983 NRC-NAS report. A storm of protest breaks out. DOE suspends its eastern repository effort.

1987: Congress mandates that DOE restrict its site characterization program to one site: Yucca Mountain, NV. Congress and DOE ignore important findings regarding dose in the 1983 NRC-NAS report. The claim of the Western Shoshones to the land is not given consideration.

1989: DOE announces that a repository will not open until the year 2010, a twelve-year postponement of the original goal.

1989–1994: Concern grows that emissions of carbon-14 from a Yucca Mountain repository could exceed EPA regulations for HLW repositories. The EPA Science Advisory Board finds (by 1994) that Yucca Mountain may not meet the standard. The consequences of carbon-14 emissions for individuals would be minute increases in radiation dose, but the global population dose over thousands of years could be very high.

1992: Congress passes the Energy Policy Act, which mandates that EPA standards generally applicable to HLW disposal not be applied to Yucca Mountain. The law requests that NAS form a committee to advise the EPA on the technical bases for setting standards for HLW disposal at Yucca Mountain.

1993–1994: DOE contractors calculate that doses from a Yucca Mountain repository to a future subsistence farmer would greatly exceed prevailing EPA standards, qualitatively echoing findings in the 1983 NRC-NAS report.

1995: The NRC-NAS committee issues its report, *Technical Bases for Yucca Mountain Standards,* but it is not unanimous. The majority recommends a new, untried method for dose calculations that could have the effect of reducing calculated dose. The lone dissenting panel member, Thomas H. Pigford, claims the committee majority created "non-scientific policy fixes" to reduce calculated doses, and chose a method for calculating doses that was not mathematically valid and would result in an intolerable loosening of generally-accepted radiation protection standards.*

1996: US Circuit Court of Appeals finds DOE liable to take charge of commercial spent fuel in 1998.

1995 and 1996: Congress considers several nuclear waste bills. One has provisions that include appointing a presidential commission on nuclear waste. The main one proposes relaxing radiation exposure standards, mandating the disposal of waste in a Yucca Mountain repository, forcing DOE to take possession of the waste beginning in 1998, and moving it to a centralized interim storage facility at Yucca Mountain. Prsident Clinton threatens to veto the bill on environmental grounds, and the bill dies in the House.

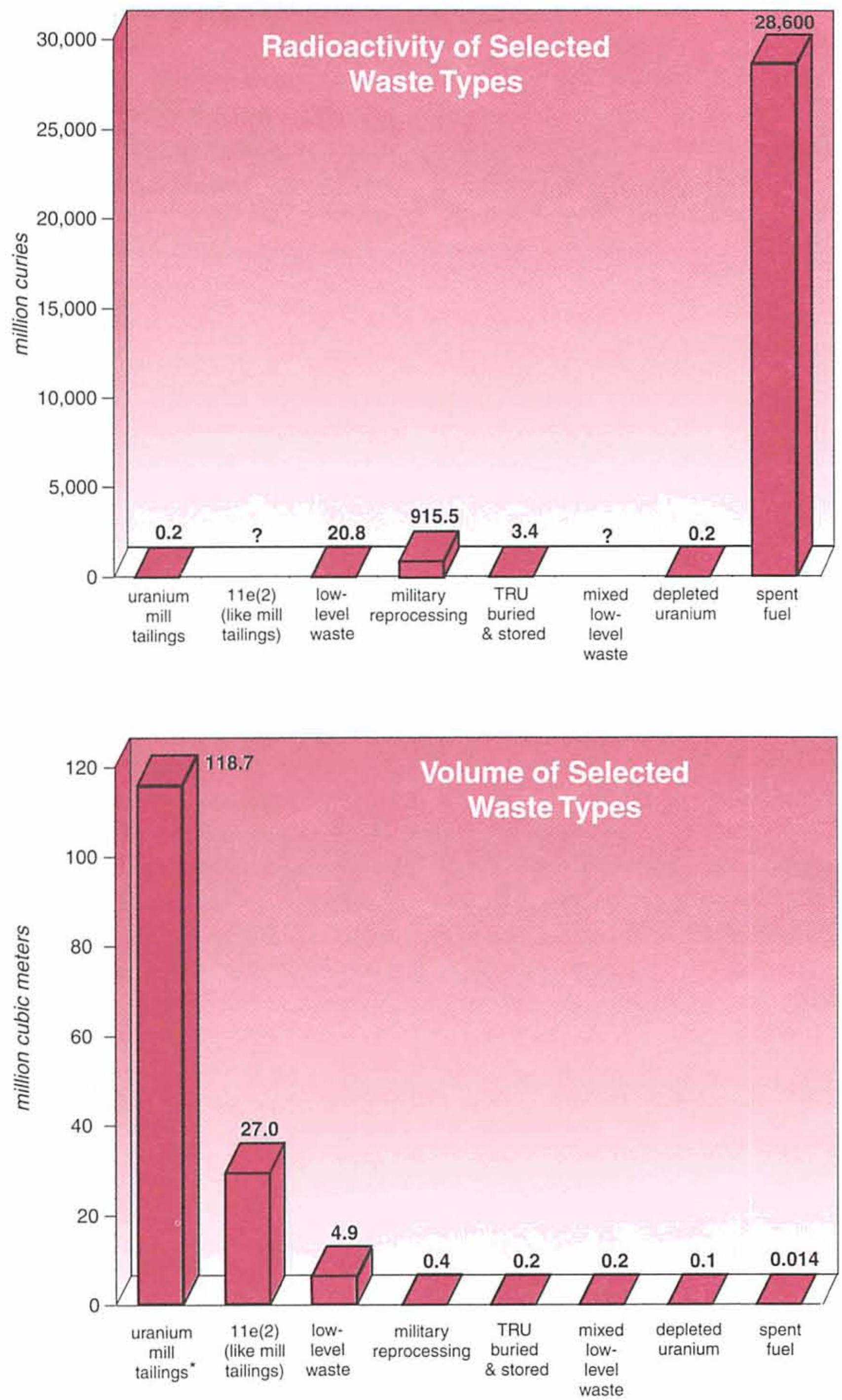
1997: Congress again considers nuclear waste legislation with provisions similar to the ones in the 1996 bill.

* See editorial, p. 3; and SDA Vol. 4 No. 4.

DOE: Department of Energy
EPA: Environmental Protection Agency
HLW: high-level waste

Centerfold, *from page 13*

unacceptable exposure risks if used for high-level waste disposal, the DOE and much of the nuclear industry have chosen to argue for more lax disposal standards and repository suitability criteria. After it appeared that the Yucca Mountain site could not meet the EPA carbon-14 standard, Congress passed a law signed by President Bush exempting Yucca Mountain from this high-level waste standard applicable to all other repositories (see "The Road to Yucca Mountain," opposite page). In another example of sidestepping Yucca Mountain's technical deficiencies, in 1995 an *ad hoc* committee of the National Research Council of the National Academy of Sciences made a recommendation for standards setting that would result in the abandonment of explicit groundwater protection, and could exclude from consideration those individuals at risk of receiving the highest radiation dose (see editorial on page 3 by Thomas H. Pigford, who dissented from this recommendation).[6]



* Volume of uranium mine tailings, not shown, is on the same order of magnitude as that of uranium mill tailings.

Source: DOE, September 1995; and DOE, December, 1996.

4. Taken as a whole, current policies entail high risks in terms of both economics and environmental protection.

DOE's cost estimates for disposal programs have continually escalated though little has actually been done to properly manage and dispose of radioactive wastes. For instance, high-level waste repository costs in constant dollars increased by about 80 percent from the time work under the 1982 legislation began to 1990. At WIPP, DOE's estimates of operation costs for the first 5 years have jumped from $531 million in 1989 to roughly a billion dollars in 1996.[7] DOE estimates WIPP's lifetime cost at $8.4 billion.[8]

Hundreds of millions of dollars have been wasted in searches for low level waste facilities under legislation from the 1980s that transferred responsibility for low-level waste disposal to the states. Billions more are being spent to stabilize uranium mill tailings and to fix the problems caused by past shallow land burial of low-level and transuranic wastes at commercial and military sites. DOE estimates the total cost for cleaning

See **Centerfold**, *page 16*

IEER's Recommendations on Nuclear Waste Management and Disposal[1]

The long-term management of long-lived, highly radioactive wastes is one of the most vexing environmental problems of our time. There are no truly safe or simple solutions, and options for management must be drawn from a menu of bad choices. An essential part of any solution is to minimize further generation of these wastes—for instance, by phasing out nuclear power.[2] But this will not solve the problem of protecting current and future generations to the greatest extent possible from already existing wastes.

We recognize that there is little agreement on how to proceed, and have therefore endorsed the idea of establishing an independent commission to conduct a comprehensive review of US nuclear waste policy. This commission should include broad public participation and should begin with an examination of the current waste classification system. The establishment of such a commission has been endorsed by dozens of public interest groups and elected officials.

IEER's own recommendations, based on our extensive review and analysis of nuclear waste issues, are given below.

1. Change how radioactive wastes are defined, and reclassify radioactive wastes and their disposal according to longevity and hazard level.

Many of the current problems with radioactive waste management stem from a flawed waste classification system (see Centerfold). A system based on the longevity and hazard of the radionuclides in the waste would not only reduce risks of potential exposure to the environment and the public, but also help provide consistency among and within the agencies and regulations that determine how waste is managed.

Existing Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) regulations for transuranic wastes implicitly define "short-lived" wastes as those which contain elements with half-lives of somewhere between 5 and 20 years. This would be a good starting point for public debate defining this crucial term, because it is preferable to store "short-lived" wastes to decay. The radioactivity of a radionuclide declines by about a thousand-fold in ten half-lives and by about a million-fold in twenty half-lives. Experience indicates that it would be imprudent to rely on institutional stability for more than 100 years, or at most 200 years. Therefore a definition of "short-lived" somewhere in the range of 5 to 20 years seems reasonable both from a technical and institutional viewpoint.

"Long-lived waste" should be defined to include radionuclides with relatively short half lives that decay into elements with long half-lives (see box p. 12). Under such a system, considerable quantities of military and commercial waste now considered "low-level" would be reclassified as "long-lived" waste, and would, in turn, require more stringent management.

2. Provide for extended on-site storage of spent fuel and other highly radioactive wastes at the point of generation (or in some cases close to the point of generation) as an interim management step, and defer reactor decommissioning in parallel with interim storage.

On-site storage will be required to help accommodate a restructured program for long-term waste management and to accomplish other health

See **Recommendations**, *page 17*

Centerfold, *from page 15*

up the waste generated by nuclear weapons production activities alone will be $227 billion over 75 years.[9]

Given the illogical waste management regulations, technically-flawed repository sites, inadequate provisions for disposing of TRU waste inventories and DOE's history of mismanagement of repository programs, it is unlikely that current radioactive waste management policies will result either in minimization of risk to future generations or wise use of financial resources.

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1 A cubic meter is about 1.3 cubic yards. The weight per unit volume of waste varies widely from fractions of a ton per cubic meter to several tons per cubic meter, depending on the density of the waste.

2 This report is currently out of print, but photocopies are available from IEER for $5. Key portions of the report are also available on IEER's website, www.ieer.org.

3 Reprocessing is the chemical treatment of irradiated reactor fuel to separate it into its constituent parts: plutonium, uranium, and fission products. It was used throughout the Cold War primarily to recover plutonium for use in nuclear weapons. See SDA Vol. 5 No. 1, or IEER's report, *Risky Relapse into Reprocessing*. Ordering information on p. 4.

4 A curie is a unit of radioactivity equal to 37 billion disintegrations per second. If a radioactive element is present in the amount of one curie, it means that 37 billion nuclei of that element undergo radioactive decay in one second, and thereby become transformed into another element.

5 Nuclear Regulatory Commission, 10 CFR Part 61.55[a][1] (Washington: US Government Printing Office, 1988).

6 For more on the 1996 NAS report see SDA Vol. 4 No. 4.

7 DOE, *The 1996 Baseline Environmental Management Report, Volume III New Mexico-Wyoming*, DOE/EM-0290, (Washington: US Department of Energy, Office of Environmental Management, Office of Strategic Planning and Analysis, June, 1996), p. 79, New Mexico section.

8 *ibid.* This estimate does not include transportation costs or waste treatment costs. Furthermore, it excludes costs for 68 of the 100 years of active institutional controls to be employed at the facility after its scheduled decommissioning in 2038. See "Reader's Note," p. 82.

9 DOE, *The 1996 Baseline Environmental Management Report, Volume I*, p. 4-1.

Recommendations, *from page 16*

and environmental goals. It should include:

- Planning for 50- to 100-year on-site storage of spent fuel in dry casks, since a sound long-term waste isolation option will not be available for many decades. Consideration should be given to shifting this waste to a site near the reactor in exceptional cases, such as that of the Prairie Island Power Plant located on a small island in the Mississippi River in Minnesota. Funds for extended on-site storage should come from the Nuclear Waste Fund, provided that utilities agree to a restructured radioactive waste management program, and abandon their support of the current flawed Yucca Mountain program and withdraw their insistence on an interim centralized storage facility for spent fuel.
- Strengthening NRC on-site storage rules to take earthquake and other risks better into account, and to ensure that casks are used only after rigorous safety certification is complete.
- Deferring decommissioning of shut-down nuclear reactors by 50 to 100 years to allow for radioactive decay that will lower radioactive waste volumes; reduce risk to decommissioning workers; and integrate on-site storage with a realistic time frame for radioactive waste disposal.
- Enforcing progress on long-term management of nuclear waste to ensure that interim on-site storage does not become permanent on-site storage.
- Rejecting any proposals for a centralized Monitored Retrievable Storage facility.
- Putting radioactive wastes, including military high-level, long-lived low-level, and transuranic wastes, into forms that will minimize risk to workers and residents from interim on-site storage, and that will not compromise in any essential way long-term management programs which may be put into place.

3. Restructure the entire long-lived waste management and disposal program.

The present programs for selection and characterization of disposal sites for low-level, high-level, and transuranic wastes have been seriously compromised both technically and politically and must be abandoned. They should be replaced with an approach to long-lived waste management and disposal that has technical integrity and institutional competence. Our suggestions for restructuring the existing programs for radioactive waste are as follows:

Present repository programs must be abandoned and replaced with an approach that has technical integrity and instrumental competence.

All wastes: Establish reasonable and enforceable rules for segregating long-lived radioactive wastes from short-lived wastes to the extent possible, and minimize generation of long-lived wastes.

Spent fuel and high-level reprocessing wastes: Cancel the current high-level waste repository development program, including further consideration of Yucca Mountain. The repository siting program should begin again with basic consideration of geology and rock types, as well as consideration of alternative approaches, such as sub-seabed disposal. Simultaneously, research and development should be pursued on engineered barriers to waste migration (including research into mimicking how natural radioactive materials are contained for long periods of time in certain kinds of geology).

Transuranic wastes: The Waste Isolation Pilot Plant repository program should be canceled and the process for long-term transuranic waste management should be integrated with the long-term high-level waste management program.

Low-level wastes: Cancel the siting for new low-level waste sites and reclassify low-level wastes, as discussed above. Store short-lived low-level wastes until the radionuclides have decayed (that is, for approximately ten to twenty half-lives). Consolidate medical and research radioactive wastes at storage locations such as closed reactor sites.

Uranium mill tailings: 1) Continue management under the Uranium Mill Tailings Reclamation Act with better controls. 2) Assess the feasibility of separating radium-226, thorium-230, and toxic metals from uranium mill tailings to enable their integration into the long-term management program for high-level waste.

Depleted uranium: Put into stable forms. In particular, convert uranium hexafluoride into oxide forms for storage.[3] Manage in the same way as transuranic waste (as part of the high-level waste program).

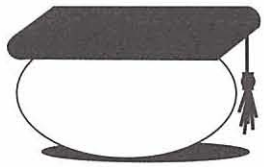
Mixed wastes: Explore environmentally acceptable ways to neutralize the non-radioactive components without substantially increasing radioactive waste volume, and preferably, reduce radioactive waste volume at the same time.

4. Restructure the institutional arrangements and policies for regulation and long-term management of long-lived highly radioactive wastes.

- Remove DOE from the long-term waste management program. Establish an independent radioactive waste management authority for repository and other programs that does not suffer

See **Recommendations**, *page 20*

It Pays to Increase Your Jargon Power



by
Dr. Egghead

1. NIMBY

a. Gumby's seldom-acknowledged pet dog.
b. Name of the cumulonimbus cloud that is the mascot of the National Weather Service.
c. A god worshipped by gymnasts in ancient Greece who wanted to increase their nimbleness.
d. Those utility executives and others who don't care where radioactive wastes are taken, as long as they are "Not In My Backyard."

2. WIPP

a. What the DOE is flagellating itself with.
b. A new waste form being tested by DOE that would immobilize long-lived radionuclides in whipped cream.
c. A device used by control freaks to keep nuclear fuel from misbehaving.
d. Acronym for Waste Isolation Pilot Plant, the DOE's proposed repository for disposal of some transuranic waste.

3. transmutation

a. The practice of not speaking to other commuters while using mass transit.
b. What cows experience when they practice transcendental meditation. Usually: "transmootation."
c. The process of converting one element into another by transforming its nucleus. It often refers to a proposed waste management technique that could theoretically transform long-lived radionuclides into short-lived radionuclides by bombarding them with neutrons.[1]

4. NRC

a. National Rifle Cleaners, a small subsidiary of the National Rifle Association.
b. Acronym for "Nuclear Rice Cakes," an experimental food produced by the DOE as part of its failed attempt to enter the health food business.
c. Acronym for Nuclear Regulatory Commission, created in 1974 when the Atomic Energy Commission was split into two parts—one for regulation of commercial nuclear activities such as nuclear power (the NRC), and one for building nuclear weapons, promoting nuclear power, and performing various energy policy-related functions (the DOE).[2]

5. half-life

a. What you have when someone tells you, "Get a life."
b. What you are left with if someone cuts your issue of *Life Magazine* in two.
c. The amount of time Half & Half will stay fresh in a refrigerator.
d. The time in which half the atoms of a radioactive element will have decayed into another element, leaving half the amount of the original element. Half of the remaining amount will disintegrate in another equal period of time. Thus, one-fourth the original amount is left after two half-lives; one-eighth after three, and so on. Half-lives of various radionuclides range from a small fraction of a second to billions of years.

6. curie

a. Something you need when you have a disease-ie.
b. The basic unit used to measure curiosity. One curie equals 0.2 queries.
c. A spice used by the French when preparing Indian dishes.
d. The traditional unit of radioactivity equal to the radioactivity of 1 gram of pure radium-226. Named after Marie Curie, who discovered radium. Equal to 37 billion disintegrations per second.

1 See Transmutation article, p. 4.

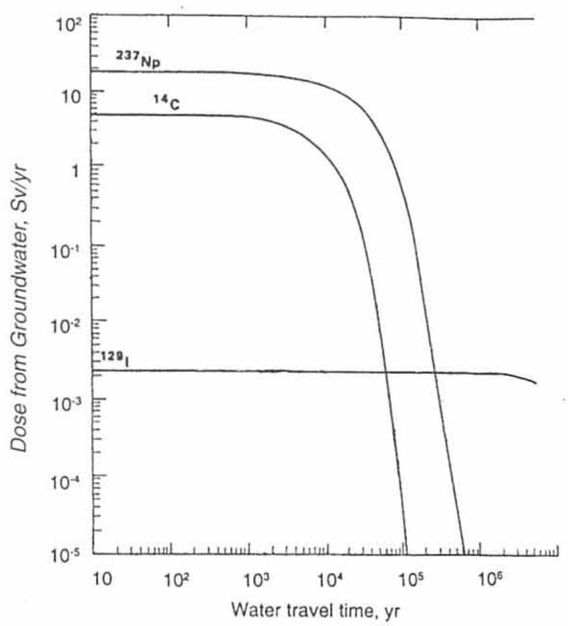
2 The National Research Council, which is a research arm of the National Academy of Sciences and National Academy of Engineering, also goes by the acronym NRC. In IEER literature, we use NRC exclusively to refer to the Nuclear Regulatory Commission.

Answers: 1) d; 2) d; 3) c; 4) c; 5) d; 6) d.

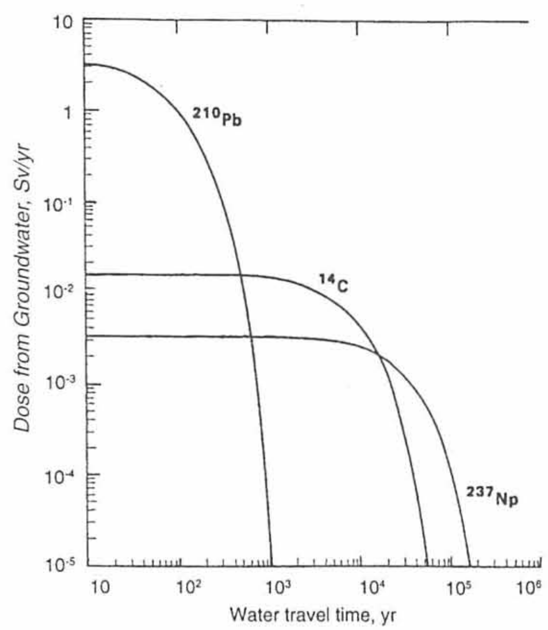
ATOMIC PUZZLER

Welcome back, puzzle players! Today Dr. Egghead is investigating possible radiation doses resulting from the disposal of high-level waste at the proposed Yucca Mountain repository. He is examining the 1983 study by the National Research Council of the National Academy of Sciences (NRC-NAS) showing the worst and best case scenarios for radiation dose to a subsistence farmer from various radionuclides in groundwater near the site. Below are two simplified graphs from the report.

Individual Radiation Dose, Worst-case Scenario



Individual Radiation Dose, Best-case Scenario



Source: Waste Isolation Systems Panel, Board on Radioactive Waste Management, National Research Council, *A Study of the Isolation System for Geologic Disposal of Radioactive Wastes*, (Washington: National Academy Press, 1983), pp. 264 and 278.

NOTE: Radionuclides omitted from "Worst-Case Scenario" graph: americium-243, lead-210, plutonium-239, plutonium-242, radium-226, selenium-79, technitium-99, tin-126, and uranium-234. Radionulides omitted from "Best-Case Scenario" graph: cesium-135, plutonium-239, radium-226, selenium-79, and tin-126.

1. For the worst-case scenario, estimate the dose per year after 1,000 years, and after 1,000,000 years from each radionuclide on the graph. (Note: The graphs are in logorithmic scale. "Water travel time, yr." is the time it takes in years for the contaminated groundwater to travel from the repository to a well.) Compare your answers to the NAS-recommended maximum individual dose of 0.0001 sieverts per year.

2. For the best-case scenario, estimate the dose per year after 100 years and after 100,000 years from each radionuclide. Again, compare your answers to the NAS-recommended maximum individual dose.

Our last issue of SDA only generated a few responses from our readers. Don't be shy! We love hearing from our readers! Congratulations to our $25 prize winner from the last puzzler:

Robin Mills of Panhandle Texas

Send us your answers via fax (301-270-3029), e-mail (ieer@ieer.org), or regular mail (IEER 6935 Laurel Ave., Takoma Park, MD 20912), postmarked by **June 15, 1997.** IEER will award 25 prizes of $10 each to people who send in a solution to the puzzle (by the deadline), right or wrong. There is one $25 prize for a correct entry, to be drawn at random if more than one correct answer is submitted.

Recommendations, *from page 17*

a conflict of interest between nuclear power and weapons production and environmental and health protection. New institutional arrangements should be made to create a program for long-term management of long-lived wastes.

- Implement policies that provide incentives to minimize further production of long-lived radioactive wastes. Specifically, when the federal government accepts spent fuel (at the appropriate time), it should be limited only to that generated by existing nuclear power plants. This agreement should not extend to any new nuclear power plants or to spent fuel produced as a result of license extensions for existing power plants.

- Establish consistent, health-based standards to govern nuclear waste management and disposal, irrespective of the process that produced those wastes. These standards should protect future generations by setting strict limits on contamination of the environment, including stringent limits on groundwater contamination. The duration of the standards should correspond to the period of time over which a risk of doses in excess of standards persists.

- Ensure that the institutions responsible for waste management understand and welcome public participation in decision-making.

[1] IEER's recommendations are based on our 1992 report, *High-Level Dollars, Low-Level Sense.*

[2] See A. Makhijani and S. Saleska, *The Nuclear Power Deception*. Ordering information is on p. 4. Key portions of this report are also available on our website, www.ieer.org.

[3] For more on depleted uranium and uranium hexafluoride, see "Dear Arjun" in SDA Vol. 5 No. 2.

Transmutation, *from page 5*

as the technology is developed. The report cites an independent cost estimate that electrometallurgical processing would be 57 percent more expensive than the PUREX process.

In sum, the study concludes that no separation or transmutation technologies could help avoid repository programs, which will remain essential to managing wastes from existing reactors.

[1] Available from the National Academy Press, Washington, D.C., $79.95 plus postage. The summary of the report can be read on the World Wide Web at: www.nas.edu.

[2] Protons in the accelerators hit a lead target at high speed and break apart lead nuclei, generating neutrons in the process.

[3] See p. 431 of the report. The costs per kWhe are calculated by IEER from the reprocessing costs in the study by assuming that fuel is irradiated to a level of 40,000 MWDth/MTHM (megawatt-days thermal per metric ton of heavy metal) and that the efficiency of the nuclear power plant is 33 percent.

The Institute for Energy and Environmental Research
6935 Laurel Avenue
Takoma Park, MD 20912

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