Going Beyond 10,000 Years at Yucca Mountain

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On July 9, 2004, the U.S. Court of Appeals (*1*) issued a ruling that denied all challenges, except one, in a set of lawsuits against the federal government's Yucca Mountain (YM) nuclear waste repository project. The successful challenge, brought by the State of Nevada, argued that the U.S. Environmental Protection Agency (EPA) had deviated from recommendations of the National Research Council of the National Academy of Sciences (NAS) (*2*) by limiting the regulatory compliance time to 10,000 years. Subsequently, the EPA has announced that it will not appeal and instead will revise the standard (*3*). Here we address several major questions that must be considered in formulating this revised standard.

In 1992 Congress passed the Energy Policy Act, directing the EPA to promulgate site-specific standards for YM "based upon and consistent with the findings and recommendations" of a NAS review. This review (*4*) generated recommendations generally consistent with the standard that EPA subsequently established (*5*). However, important differences remained in the recommendations and justification for the compliance period. EPA chose a 15 mrem per year dose limit with the same 10,000-year period for compliance assessment (*6*) as used previously for the Waste Isolation Pilot Plant repository in New Mexico.

The NAS report concluded that there is "no scientific basis for limiting the time period of the individual risk standard to 10,000 years or any other value." (*7*) Instead the report recommended that assessment be performed out to the time of peak risk, which may be several hundred thousand years in the future. However, the report included two important caveats (*8*):

> "We note that although the selection of a time period of applicability has scientific elements, it also has policy aspects that we have not addressed. For example, EPA might choose to establish consistent policies for managing risks from disposal of *both* long-lived hazardous non-radioactive materials *and* radioactive materials.
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> "Another time-related concern *can* affect the formulation of the safety standard. This is based on ethical principles, and is the issue of intergenerational equity [(*9*)]." (emphasis added)

To address these NAS recommendations, four questions must be considered. (1) What risks might YM pose 10,000 to 1-million years from now? (2) How does the U.S. currently regulate other comparable long-term risks? (3) How might a revised YM standard affect near-term human welfare and long-term risk? (4) How should the YM standard be revised if intergenerational equity and consistent management of all risks are considered to be reasonable policy goals?

Post-10,000-year risks at Yucca Mountain

Currently, the best available understanding of potential long-term performance at YM comes from the 1999 Final Environmental Impact Statement (FEIS). Figure 1 shows FEIS predictions for radiation doses to individuals using water from the point of highest concentration in a simulated groundwater plume entering the Amargosa Valley. The effects of canister degradation beyond 60,000 years and of subsequent periodic increases in groundwater infiltration during glaciation cycles are clearly seen.

The primary long-term risk occurs if future Amargosa Valley residents have technology for irrigated agriculture, but do not employ basic public health measures to test water quality and to take simple mitigative actions. In this worst case, the maximum doses predicted by the FEIS would be of the same order as natural background radiation.

Consistent management of other long-term risks

Current human activities generate a myriad of potential long-term risks, but also create technological, scientific, institutional, social and physical infrastructure that future generations can use to manage these risks (*10*). Over millennial time scales, many current human activities can be expected to generate significant environmental and public health effects. For example, current scientific understanding suggests that that 20th and 21st century carbon dioxide emissions may cause substantial changes in ocean chemistry (*11*) and complete melting of Greenland glaciers, raising sea levels by 7 meters (*12*).

Current activities also generate wastes with persistent or permanent hazards, including mining wastes; coal ash; deep-well injected hazardous liquid waste; and solid wastes such as lead, mercury, cadmium, zinc, beryllium, and chromium managed at Resource Conservation and Recovery Act (RCRA) sites and Superfund sites.

For these wastes the longest compliance time required by the EPA is 10,000-years for deep-well injection of liquid hazardous wastes (*13*). For all forms of shallow land disposal compliance time requirements are substantially shorter. For RCRA Solid Waste Management Facilities, a typical permit is for 30 years, and the operator bears responsibility over a time horizon less than a century (*14*). The acceptable frequency of disruptive events can be deduced from the requirement that RCRA sites not lie in a 100-year flood plain, or if they do, be designed to resist washout by a 100-year flood (*15*). Coal and mining wastes are excluded from the definition of hazardous wastes by statute.

Short compliance time requirements do not imply the absence of potential long-term harm. Okrent and Xing, for example, analyzed a postulated RCRA site for arsenic, chromium, nickel, cadmium and beryllium. Assuming a loss of societal memory and that no monitoring or mitigation occurs, individuals in a farming community at the site 1,000 years in the future were estimated to face a 30% lifetime probability of cancer (*16*).

Near-term risks and benefits

Current statute would permit storage of up to 63,000 metric tons of commercial spent fuel at Yucca Mountain, representing a near-term economic benefit of one-trillion dollars of electricity (*17*). Cancellation of the YM project would result in loss of the $ 8 billion spent to date for site selection and characterization. The statute would transfer the cost of repeating site selection and characterization, except a fraction attributed to military wastes, to nuclear electricity consumers through adjustment of the current 0.1 cents per kilowatt-hour Nuclear Waste Fund fee. All costs associated with the increased duration of commercial on-site storage—approximately $360 million per year—will be paid by tax monies (*18*). Additional costs for protracted management of military high-level wastes at the Hanford, Savannah River, and Idaho sites will be borne by taxpayers. This large expenditure of tax and consumer funds would eliminate opportunities for other—likely far more efficient—investments to improve human welfare.

The revised standard will also affect the competition between the two primary fuels for base-load electricity production—nuclear and coal. U.S. utility executives uniformly maintain that YM licensing is a necessary ingredient for public acceptance of new nuclear construction (*19*) as an alternative to the 62 gigawatts of new U.S. coal construction now being planned due to increasing natural gas prices (*20*).

For comparison, electricity production equivalent to 63,000 MT of spent nuclear fuel would require mining and burning 5-billion tons of coal—6 years of current U.S. coal consumption—generating 700-million MT of ash and flue-gas desulfurization sludge requiring shallow land disposal, releasing over 650 MT of mercury, and resulting in 300 U.S. coal-worker fatalities (*21*). Furthermore, the actual capacity of the 2000-acre YM site is substantially larger than 63,000 MT, 2.5 to 5 times larger for the disposal of spent fuel, and some 50 times larger for the disposal of residual wastes from advanced fuel cycles (*22*). This suggests the potential for much different energy technology trajectories with, or without, a YM repository, and large differences in potential near and long term environmental and public health impacts.

Selecting a consistent post-10,000-year standard

The EPA must write its revised YM standard on a blank slate, because no precedent exists for regulating waste risks past 10,000 years. And in order to achieve consistent regulation EPA must either leave the slate blank, or select a YM standard that could reasonably be applied in the future to all wastes. We propose two elements for any revised standard for periods well beyond 10,000 years:

1) Long-term risks must be clearly justified by near-term benefits.

2) Public health and safety should be protected from substantive harm, to a level consistent with reasonable long-term management of other hazardous materials. We would argue that mean radiological doses below natural background, as predicted in the FEIS (Fig. 1), would not qualify (*23*) as doses leading to substantive harm.

For the many millennia that precede significant canister degradation, future generations can readily remove waste from YM. Unfortunately, most other long-term environmental impacts cannot be reversed with similar ease. Thus, any revised YM standard should be designed to set a precedent that we could reasonably aspire to, in the future, for the management of all types of long-lived hazardous wastes.

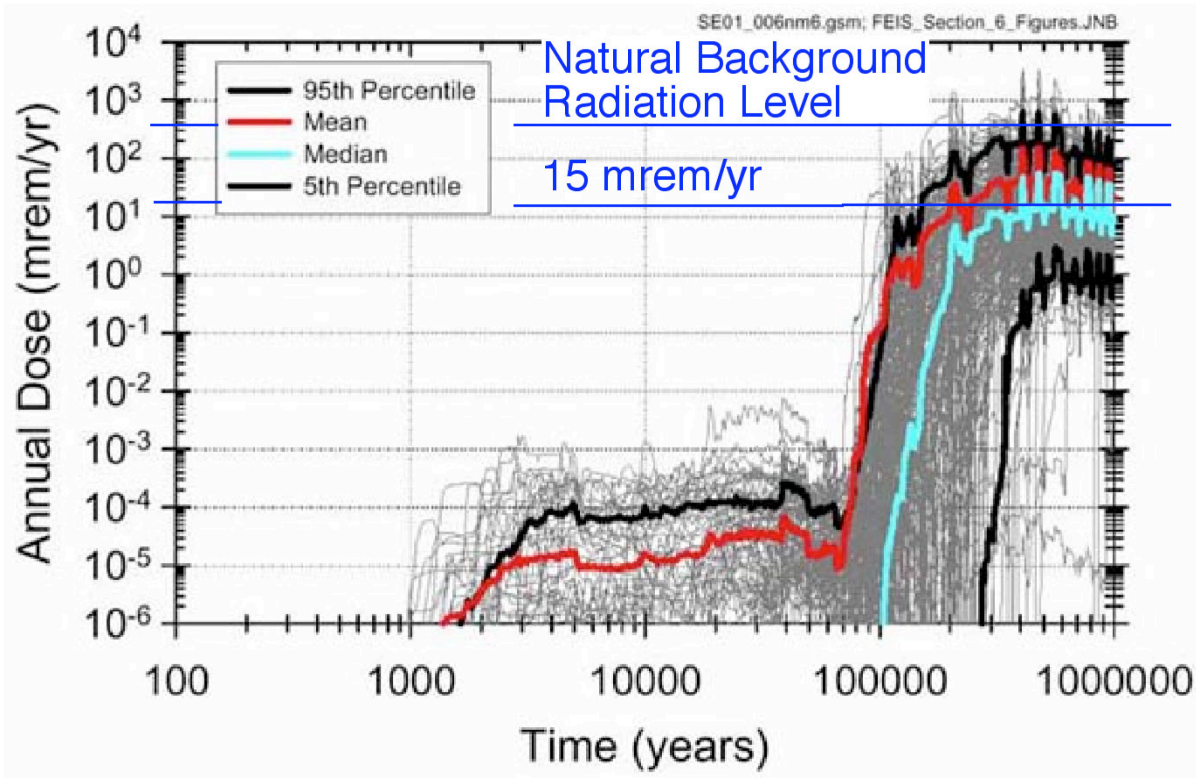

Figure 1. Yucca Mountain FEIS annual dose prediction based on 300 probabilistic simulations (*24*).

References and Notes

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14 . Okrent, *ibid*. p. 888.

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17 . For electricity valued at 5 cents per kilowatt hour, and an average fuel burnup of 40,000 MWd(t)/MT and plant efficiency of 0.33 MWd(e)/MWd(t).

18 . Based on the recent U.S. Court of Appeals decision on DOE liability for delays in accepting waste for 17 Exelon reactors, with an estimated cost of $300 million between 2011 and 2015, scaled to 103 reactors.

19 . O. Kingsley, Chairman of Nustart Corp., quoted in *Nuclear News*, p. 37, Aug. 2004.

20 . M. Clayton, "America's new coal rush," *The Christian Science Monitor*, Feb. 26, 2004.

21 . Okrent, *ibid*. p. 887.; National Institute for Occupational Safety and Health (NIOSH), "Worker Health Chartbook, 2000: Focus on Mining," Table 1, 2000.

22 . P.F. Peterson, *The Bridge,* **33**, 26 (2003).

23 . Using BEIR V (National Academy Press, 1990) risk of 0.0005 fatal cancers/rem, over a 70-year exposure period natural radiation exposures of 0.36 rem/year give a cancer risk of 1.2%.

24 . DOE, Total System Performance Assessment - Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain, REV 00, ICN 02, December 2001.