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PROPOSED ENVIRONMENTAL STANDARDS FOR YUCCA MOUNTAIN, NEVADA

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ABSTRACT

The Environmental Protection Agency (EPA) has proposed radiation protection standards for the potential spent nuclear fuel and high-level radioactive waste disposal system in Yucca Mountain, Nevada. These standards will be in Part 197 of Title 40 of the Code of Federal Regulations (40 CFR Part 197). The Energy Policy Act of 1992 directed EPA to take this action based upon input from a contract with the National Academy of Sciences (NAS). The EPA received the NAS Report, entitled *Technical Bases for Yucca Mountain Standards*, on August 1, 1995.

The proposed 40 CFR Part 197 contains the following standards. The proposed storage standard is 150 microsieverts (μSv) annual committed effective dose equivalent (CEDE) to any member of the general public. The proposed disposal standards are: (1) 150 μSv annual CEDE to the reasonably maximally exposed individual (RMEI) for 10,000 years after disposal; (2) the peak dose received by the RMEI after 10,000 years must be projected and placed into the environmental impact statement; (3) 150 μSv annual CEDE to the RMEI within 10,000 years after disposal as a result of human intrusion; however, if the intrusion could not occur until after 10,000 years, the results would not be placed in the license application but must be placed in the Yucca Mountain environmental impact statement; and (4) the levels of radionuclides in the ground water cannot exceed the maximum contaminant levels which have been established under the Safe Drinking Water Act. The EPA also requested comments upon whether to include assurance requirements and requirements for the use of expert elicitation.

The EPA had a public comment period of 90 days (which ended November 26, 1999) and public hearings in Amargosa Valley, Nevada; Las Vegas, Nevada; Washington, D.C; and Kansas City, Missouri. The final standards are to be issued by late summer of 2000.

INTRODUCTION

The Environmental Protection Agency (EPA) has proposed radiation protection standards for the potential spent nuclear fuel and high-level radioactive waste disposal system in Yucca Mountain, Nevada (1). (The term "repository" is used in this paper to refer to the mined facility, while the term "disposal system" is used to refer to the entirety of the mined facility and the engineered barrier system.) The Energy Policy Act of 1992 (EnPA) directed EPA "to set generally applicable standards for the Yucca Mountain site...for protection of the public from releases from radioactive materials stored or disposed of in the repository at the Yucca Mountain site." (2) It also directed EPA to set the standards "based upon and consistent with" the results of a contract with the National Academy of Sciences (NAS) to "conduct a study to provide [to EPA]...findings and recommendations on reasonable standards for protection of the public health and safety..." (2). The EPA received the NAS Report, entitled *Technical Bases for Yucca Mountain Standards* (3), on August 1, 1995. When finalized, the standards will be in Part 197 of the Title 40 of the Code of Federal Regulations (40 CFR Part 197).

In previous papers, EPA has reported upon the findings and recommendations in the NAS Report, public comments received from the review of the NAS Report, and the range of the EPA's considerations while establishing standards based upon the NAS Report's findings and recommendations. This paper reviews the proposed standards and plans for finalizing the standards.

STORAGE STANDARD

Subpart A of 40 CFR Part 197 contains the storage standard. It will cover the public doses resulting from management and storage which occurs prior to closure of the repository. The NAS did not address storage. The proposed standard was 150 microsieverts (μSv) annual committed effective dose equivalent. (CEDE). "Annual committed effective dose equivalent" is the CEDE resulting from one year's intake of radionuclides plus the annual dose resulting from external dose. It would apply to any member of the public in the general environment. The general environment is anywhere outside the Yucca Mountain site, the Nellis Air Force Range, and the Nevada Test Site. The standard is actually the combined doses of exposure resulting from management and storage occurring within the repository and the activities on the surface. 40 CFR Part 197 will cover the underground activity while Subpart A of 40 CFR Part 191, *Environmental Radiation Protection Standards for Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (4), will cover the surface activity. This is the result of the EnPA stating that EPA is to set standards for "radioactive materials stored...in the repository." Therefore, EPA proposed to have 40 CFR Part 191 cover exposure from the surface activities.

DISPOSAL STANDARDS

Subpart B of 40 CFR Part 197 contains proposed standards for: (1) protection of individuals; (2) human intrusion; and (3) protection of ground water. The disposal phase is considered to start when the repository is closed. Disposal was the subject of the findings and recommendations of the NAS Report (3).

Role of the NAS Report

An early question which arose is whether EPA is bound to follow the NAS' findings and recommendations. Many of those findings and recommendations are written in a non-binding manner because the NAS recognized that many of the issues are not scientific or technical but rather societal policy issues to be determined through an EPA public rulemaking process. Therefore, it is clear that these are non-binding. But what about those findings and recommendations which are stated in relatively definite terms?

The EPA does not believe that Congress intended for public rulemaking to be bypassed since the EnPA stipulated that the standards be "promulgated by rule." Also, the Conference Report accompanying the EnPA stated, "The provisions of section 801 [of the EnPA] are not intended to limit the Administrator's [of EPA] discretion in the exercise of his discretion in the exercise of his authority related to public health and safety issues" (5). In addition, it is a Constitutional principle that setting standards may only be done by Federal employees. Therefore, if the NAS' findings and recommendations were to be considered mandatory, there could be a Constitutional issue (6). In summary, EPA does not believe that it is bound to adopt the NAS' findings and recommendations. However, the NAS' findings and recommendations played a dominant role in the deliberations and will continue to do so.

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Reasonable Expectation

All of EPA's radioactive waste disposal standards are based upon the concept of "reasonable expectation." Reasonable expectation means that the Nuclear Regulatory Commission (NRC) is satisfied that compliance will be achieved based upon the full record before it. Reasonable expectation is used by EPA to recognize that absolute proof is neither necessary nor possible to obtain since performance of the disposal system must be projected for at least 10,000 years. It is also intended to be less stringent than the concept of "reasonable assurance" that NRC has used in the licensing of nuclear power reactors. The difference between trying to project performance of an engineered system with a cumulative experience of hundreds of years of operation versus projection of the performance of a new type of combined engineered and natural system with no operational experience is clear. The EPA is trying to recognize that the uncertainty involved in projecting the performance of a disposal system is inescapably much greater than for a reactor. Further, "reasonable expectation" is intended to be cautiously realistic in that it does not exclude important parameters simply because they cannot be quantified to a high degree of confidence whether they contribute to or detract from repository performance. That is not to say that parameter values can be arbitrary, but rather, that ignoring effects of parameters (the values of which are reasonable based upon research or expert judgment) or using only extreme values can lead to assessments of performance which have a high probability of being unrealistic or have such low probability of occurring that they would not be representative of the range of likely performance.

Individual-protection Standard

Form. One significant question associated with this standard was whether it should be stated in terms of risk or dose. The NAS recommended risk, whereas the EnPA stated that the standard was to be a dose limit. The EPA decided to use dose for five reasons. First, advisory bodies such as the International Council on Radiation Protection and the National Council on Radiation Protection have recommended that standards be stated in dose. Also, most existing national and international radiation standards are stated in dose. Second, EPA has an established methodology for calculating dose found in *Federal Guidance Reports 11* and *12* (7 and 8, respectively). There is no corresponding methodology for risk. Third, dose and risk are closely related mathematically. In addition, the dose standard is based upon the lifetime risk of an individual developing a fatal cancer (using the linear, non-threshold, dose-response relationship). Therefore, risk is the basis for the limit. Fourth, the EnPA called for a dose limit. And, finally, most commenters on the NAS Report favored dose.

Level. The individual-protection standard was proposed to be 150 μSv annual CEDE. The NAS recognized that the appropriate level is a question of both science and public policy. There were several bases for the proposed level. First, it is within the range which the NAS recommended. The NAS stated that a starting point for the rulemaking should be within an annual risk of 10^{-6} to 10^{-5} -- about 20 to 200 μSv per year. Second, it represents a lifetime risk of about 3×10^{-4}. This is about the upper value of the range of the risk which EPA generally uses to judge the acceptability of non-radiation-related activities. The EPA generally considers a range of about 10^{-6} to 10^{-4} lifetime risk as an acceptable risk range for regulation. And, finally, it is consistent with the individual-dose limit in 40 CFR Part 191 which is the basis for the certification of the Waste Isolation Pilot Plant (WIPP) and the forthcoming decision on the Greater Confinement Disposal system.

The representative of the exposed population. The NAS recommended that EPA use the average risk within a critical group to determine compliance with the individual-protection standard. They cited two examples of critical groups which might be used. One example was a statistical construct based upon the current environment and population in the vicinity of Yucca Mountain. Ranges of parameter values

relevant to environmental and population characteristics would be used together with projections of radionuclide concentrations in Monte Carlo analyses to estimate the risk to groups of exposed people. The average risk among these groups would be used to determine compliance. The other example was a group of subsistence farmers. A range of the risk to the most highly exposed farmers who grow all their food and get all their drinking water from the contaminated aquifer is calculated. The average of the risk in this group is used for compliance determination.

However, EPA proposed a reasonably maximally exposed individual (RMEI). As opposed to critical group, this concept has been used by EPA in other programs. The concept is similar to the critical-group concept in that its purpose is to project doses which are within a reasonably expected range rather than the highest theoretical dose. This is accomplished by determining which parameters make the largest difference in the results. Then one or a few of these are assumed to be at a maximum value while the others are kept at their average values. The proposal is based upon what EPA believes is a common lifestyle in Amargosa Valley, Nevada which EPA calls "rural-residential." This is a person who has a garden but would earn income from other work in the area. This person would consume two liters per day of ground water and a portion of their diet would be from locally grown food which was grown using the ground water.

Location of the individual. The location for the RMEI was proposed to be about 20 kilometers south of the repository at an intersection of two highways, called Lathrop Wells, in Amargosa Valley. It appears that an individual could reside anywhere from about five kilometers to 30 or more kilometers from the repository. However, the ability of an individual to reside at any particular point is dependent upon that person's purpose and resources since the ground water is deeper near the proposed repository (about 300 meters in depth) and decreasing in depth with distance from the repository until there are surface discharges 30 to 40 kilometers away. The EPA believes that the rougher terrain and expense of recovering water significantly north of Lathrop Wells would discourage settlement by individuals, particularly since water is more easily accessed just a few kilometers farther south. The EPA also found that commercial agriculture is unlikely as far north as Lathrop Wells because of the cost of water recovery, but that it would be reasonable to assume that a rural-residential individual could live there and have a garden using some of the water recovered for domestic purposes. The EPA also believes that an individual living in this location would be among the most highly exposed individuals even though water closer to the repository would likely contain higher concentrations of radionuclides. This is counterintuitive until you remember that EPA believes that individuals would not live closer because of the cost of recovering that water.

Ground-water Protection Standards

Level of protection. Water which flows under Yucca Mountain is being used for drinking water by members of the public starting as close as 20 kilometers south of the proposed disposal system. Since ground water is particularly valuable in this desert setting and is the sole source of water south of Yucca Mountain, EPA believes that it should be separately protected. The overall goal is to prevent adverse effects upon human health and the environment by preventing contamination rather than relying upon later mitigation. The proposed level of protection is the same as is contained in the maximum contaminant levels (MCLs) for radionuclides which were previously established by EPA under the Safe Drinking Water Act (9). This approach provides the same protection regarding Yucca Mountain that exists elsewhere in the country for other waste disposal projects. The MCLs which were proposed are: (1) 5 picocuries per liter of combined radium-226 and radium-228; (2) 15 picocuries per liter of gross alpha activity; and (3) 40 μSv per year from combined beta and photon radiation from man-made

radionuclides. The time frame for these standards is 10,000 years of undisturbed performance, i.e., the repository is not affected by human intrusion or unlikely natural processes or events.

Representative volume. The EPA also proposed the concept of a representative volume of ground water. This would be the volume of ground water in which the concentrations of radionuclides would be calculated. The intent is to provide a basis which is conservative but reasonably implementable. In other words, EPA believed that it is unreasonable to require projections of concentrations in small volumes, for example, a few gallons of water in a fracture. On the other extreme, it was neither reasonable nor conservative to assume that all of the water in an entire hydrologic sub-basin would be involved.

The EPA considered four different volumes (the metric volumes listed are approximate). The smallest was 12,380,000 liters (10 acre-feet). This would be the volume used by a community of 25 people for domestic purposes or a non-farming family of four with a garden. It is also the lower bound for the amount of water which would be used in a public water supply (which is defined as a system serving at least 25 people). The next largest volume considered was 148,560,000 liters (120 acre-feet). The basis of this volume is a community of 150 people. This population was intended to reflect the estimated population increase over the next 20 years around Lathrop Wells. It was also assumed that this community would likely use water for more than just domestic purposes, such as light industrial or tourist use. The EPA proposed the third largest volume considered, 1,591,023,000 liters (1,285 acre-feet). This volume is based upon the average size of an alfalfa farm in Amargosa Valley, Nevada, i.e., about 103 hectares (255 acres). The estimated annual irrigation rate is about 6,190,000 liters (5 acre-feet) per acre. Multiplying the two values yields 1,578,450,000 liters (1,275 acre-feet) per year. An extra 12,380,000 liters (10 acre-feet) per year is added for domestic use of 25 people in the community. And, finally, the Agency considered 4,952,000,000 liters (4,000 acre-feet) per year. This is representative of the estimated perennial yield of the Jackass Flats hydrologic sub-basin, i.e., the amount of water which could be removed from the sub-basin without significantly decreasing the yield and quality of water in the future.

To calculate the concentrations of radionuclides in the representative volume, EPA proposed two approaches, either of which may be used by the Department of Energy (DOE). The first approach is termed the "well-capture zone." In this approach, the dimensions of the representative volume are based upon a well which is pumping an annual volume equal to the volume of the representative volume. The dimensions of the well-capture zone are determined by the pumping rate in combination with aquifer characteristics such as hydraulic conductivity and gradient, and the length of the screened interval of the well. The DOE must assume that the well has characteristics consistent with public water supply wells in Amargosa Valley and that the screened interval of the well is centered in the highest concentration in the contamination plume. The second approach is termed the "slice of the plume." This approach is based upon a cross-section of the plume of contamination with sufficient thickness parallel to the prevalent flow of the plume of contamination that it contains the representative volume. The DOE and NRC must determine where the edge of the plume of contamination is, for example, where the concentration falls to 0.1% of the highest concentration. Finally, the "slice" must be perpendicular to the prevalent flow of the aquifer.

Point of compliance. The EPA proposed four potential points of compliance. They range in distance from five kilometers to about 30 kilometers from the repository. There are two concepts for the points of compliance. First is the controlled area. This is the concept used in 40 CFR Part 191. A controlled area is an area and its underlying geology in which the ground water standards would not apply. This means that the standards must be met anywhere outside of the area. Compliance is generally determined at the boundary of the controlled area. The second approach is to name a specific point based

upon the understanding of the ground water flow and economic and land use factors in the area. This approach necessitates a contingency provision in case the ground water flow or other factors are found to not meet the underlying understanding with the result that the highest concentration is found somewhere besides the specified point.

The first alternative is a controlled area. It would be defined the same as in 40 CFR Part 191, i.e., the boundary of the area could be no farther than five kilometers from the waste and the area could not exceed 100 square kilometers. This is the same requirement under which the WIPP disposal system was certified.

The second alternative would specify a point location. That point would be at Lathrop Wells (about 20 kilometers from the waste). The depth to ground water in this location is about 110 meters.

The third alternative is again a point which would be determined by DOE and NRC within a specified area about 30 kilometers south of the emplaced waste. This area encompasses a large part of the agricultural area in southern Amargosa Valley. The depth to ground water in this area is roughly 20 to 40 meters.

In case the ground water does not flow in the direction which is now thought, for the second and third alternatives, a new point of compliance must be established at the same distance from the emplaced waste as the original point but centered over the highest concentration of radionuclides.

The fourth and final alternative is a controlled area. This could be considered a combination of two controlled areas. The first would be limited to a distance of five kilometers from the emplaced waste. The second would be the current boundary of the Nevada Test Site. These two areas overlap. Where they overlap, the Nevada Test Site boundary would be the boundary to be used. If the ground water flows southward from the waste (as currently thought) and the Department and NRC use the southern boundary of the Nevada Test Site, the edge of this controlled area would be about 18 kilometers from the emplaced waste.

Human-intrusion Standard

One of the issues which Congress asked the NAS to address was whether active institutional controls could effectively stop human intrusion into the disposal system. The NAS found that active institutional controls could not stop human intrusion at the Yucca Mountain site. The NAS recommended that EPA assume that an intrusion will occur at Yucca Mountain (rather than using a probabilistic approach) and establish an appropriate scenario for DOE to analyze. They also recommended that EPA establish a standard as a test for the resiliency of the repository and set it at the same level as the individual-protection standard.

The EPA proposed a single-borehole intrusion scenario. The borehole was assumed to be used for water exploration as is common in the Yucca Mountain vicinity. This scenario was used to establish the basic parameters values for the diameter and other characteristics of the borehole. The DOE is then to assess the dose received by the RMEI as a result of only the releases which occur through the borehole and without any unlikely natural processes or events occurring.

The timing of the intrusion was established based upon the projected lifetime of the waste packages. The time of the intrusion is specified to be earliest time that the drillers could penetrate a waste package without recognition by the drillers. Also, there would be a small percentage of the waste

packages which had failed but significant migration of radionuclides had not occurred, and the intrusion could not be assumed to occur during the period of active institutional control.

There were two alternatives proposed for the standard. They both limit the annual CEDE to 150 μSv. However, the first alternative limits the consideration to the first 10,000 years after disposal. The second alternative recognized that an intrusion might not be able to occur prior to 10,000 years. Therefore, in addition to the dose limit for the first 10,000 years, there is a requirement that the results of the analysis and its bases be placed in the Yucca Mountain environmental impact statement as an indicator of long-term performance following the intrusion.

OTHER CONSIDERATIONS

Lower limit on processes and events to be considered. In 40 CFR Part 191, there is a lower limit on the probability of events and processes which need to be considered in the performance assessment. That provision is that the events and processes which have a probability of less than 1 in 10,000 of occurring within 10,000 years after disposal did not need to be included in the analyses. The same limit was proposed for Yucca Mountain in 40 CFR Part 197.

Underground injection. This issue was first brought to EPA's attention in the law suit challenging the original (i.e., 1985) 40 CFR Part 191 (10). In remanding the disposal standards to EPA, the court found that a geologic repository might be a form of underground injection. The EPA later issued amendments to the disposal standards in 40 CFR Part 191 in response to the court's remand (11). In the preamble to the amendments, EPA concluded, based upon a review of the Safe Drinking Water Act (9), its legislative history, and the regulations governing the underground injection control program, that disposal of containerized radioactive waste in geologic repositories does not constitute underground injection. The same conclusion was proposed for the Yucca Mountain disposal system.

Assurance requirements. In 40 CFR Part 191, EPA included several qualitative principles which were intended to supplement the protection afforded by the quantitative standards because of the inherent uncertainty in the required long-term projection of disposal system performance. Those requirements covered the need for passive and active institutional controls, monitoring, the use of multiple barriers, the need to be able to locate and remove the waste after disposal, and the need to avoid areas with natural resources unless the advantages of the site outweighed the potential for the increased probability of human intrusion. These provisions were not proposed for Yucca Mountain, however, EPA did request comments on including such requirements.

Expert elicitation. The EPA also considered setting guidelines for the use of expert elicitation in concert with performance assessments and solicited comments upon doing so. The provisions considered were: (1) the NRC needs to consider the source and use of the information; (2) to the extent possible, experts with appropriate expertise and independence from the DOE will be chosen for the panel; and (3) DOE should present information to the panel in a public meeting with an opportunity for other qualified experts to present information, also. The EPA would also allow NRC to use the results of expert elicitations which were completed prior to the finalization of 40 CFR Part 197.

PUBLIC PARTICIPATION AND FUTURE STEPS

The EPA published the proposed standards in the August 27, 1999 *Federal Register* (11). A public comment period was open from then until November 26, 1999. Public hearings were held in

Washington, D.C. on October 13; Amargosa Valley, Nevada on October 19; Las Vegas, Nevada on October 20-21; and Kansas City, Missouri on October 27.

The proposed standards and other information regarding the Yucca Mountain standards may be accessed on the EPA World Wide Web site at http://www.epa.gov/radiation/yucca. There is also a toll-free telephone information line at 1-800-331-9477.

It is EPA's goal to issue the final standards by late summer of 2000. At the same time, the Agency will release its response-to-comments document and the final version of the background information document and economic evaluation.

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