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FAULTY ASSUMPTIONS FOR REPOSITORY REQUIREMENTS

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ABSTRACT

Long term performance requirements for a geologic repository for spent nuclear fuel and high-level waste are based on assumptions concerning water use and subsequent deaths from cancer due to ingesting water contaminated with radio isotopes ten thousand years in the future. This paper argues that the assumptions underlying these requirements are faulty for a number of reasons. First, in light of the inevitable technological progress, including efficient desalination of water, over the next ten thousand years, it is inconceivable that a future society would drill for water near a repository. Second, even today we would not use water without testing its purity. Third, today many types of cancer are curable, and with the rapid progress in medical technology in general, and the prevention and treatment of cancer in particular, it is improbable that cancer caused by ingesting contaminated water will be a significant killer in the far future.

This paper reviews the performance requirements for geological repositories and comments on the difficulties in proving compliance in the face of inherent uncertainties. The already tiny long-term risk posed by a geologic repository is presented and contrasted with contemporary every day risks. A number of examples of technological progress, including cancer treatments, are advanced. The real and significant costs resulting from the overly conservative requirements are then assessed. Examples are given of how money (and political capital) could be put to much better use to save lives today and in the future. It is concluded that although a repository represents essentially no long-term risk, monitored retrievable dry storage (above or below ground) is the current best alternative for spent fuel and high-level nuclear waste.

I. INTRODUCTION

The most glaring aspect of the nuclear waste problem is that the U.S. has not been able to progress toward geological disposal as planned. It is the author's contention that this is due in no small part to the requirements for the disposal of spent nuclear fuel and high-level radioactive waste 10,000 years hence. These requirements are too conservative because they are based on the faulty assumption that no progress in science and technology, important to the assessment of risk, will take place in that time. This is not a new concept, but it is an important consideration that is consistently ignored. Because it is impossible to know in detail what society and technology will look like in the far future, calculations of risk to individuals and society have assumed that today's society and technology will not change. This has led to difficult and costly efforts to assure compliance with requirements that a geologic repository system limit the release of radioactive waste for thousands of years.

The requirements are based on the risk that in the far future, ten thousand years from now, an individual or individuals could contract cancer and die prematurely as a result of ingesting water contaminated with radioactive waste from a

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repository. The water presumably has come from a well drilled to obtain potable water. In the case of Yucca Mountain this would mean drilling for water in a desert. It is unlikely that future generations will have to resort to such uncertain water supplies.

A simple but still ignored fact is that today we would not use a water supply without testing the quality of the water, and it is unthinkable that future generations would not find testing water even easier and more effective. In fact, with the progress in underground monitoring that could occur it is possible that contaminated water could be detected before a well was developed.

Less obvious, but very important is the fact that medical science is making very significant progress in preventing and treating cancer. Noting that science and technology in general, and medical science and technology in particular, are progressing at an increasing rate, it is hard to imagine that cancer caused by ingesting contaminated water will be a problem ten thousand years from now.

What is being stated here is that the assessment of risk from a geologic high-level waste repository, assuming no progress in science and technology, is not an adequate basis for deciding how to spend our resources to best protect the present and future generations.

II. LONG-TERM REQUIREMENTS

The NRC is improving the regulatory structure with the development of a new rule, 10CFR63. This rule eliminates subsystem requirements, and the unreasonable mandate to take into account anticipated and "unanticipated" processes and events.[1] However, long-term requirements remain. The new rule limits releases for 10,000 years. "The engineered barrier system shall be designed so that, working in combination with natural barriers, the expected annual dose to the average member of the critical group shall not exceed 0.25 mSv (25 mrem) TEDE at any time during the first 10,000 years after permanent closure, as a result of radioactive materials released from the geologic repository."[2] Further, 10CRF63.115(b)(2) specifically states that progress cannot be considered. "Changes over time in the behaviors and characteristics of the critical group including, but not necessarily limited to, land use, lifestyle, diet, human physiology, or metabolics; shall not be considered.[3]

At this writing the EPA is planning on releasing a new rule pertaining to the release of radionuclides. The new rule will, in all likelihood, apply over the long-term, i.e. for 10,000 years. Currently 40CFR191.13 requires less than a 10% chance of release exceeding specified limits for 10,000 years, and less than 0.1% chance of exceeding ten times those limits. Limits for individual radionuclides are specified in Appendix A to Part 191.[4] The uncertainty in the details of the geologic medium, the forecasting of geologic events, and the performance of the engineered barrier system (repository/waste package/waste form) for long times in the future make it essentially impossible to prove compliance with the required performance standards. However, it is important to note that the EPA does not require "proof" of compliance. 40CRF191.13(b) states, "Performance assessments need not provide complete assurance that the requirements of § 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with § 191.13 (a) will be achieved."

It seems to this author that there is problem with the interpretation of "reasonable expectation." A "conservative" interpretation of reasonable expectation is most often adopted in the name of minimizing the risk to future generations. The difficulty with this approach is that it allows the opponents of nuclear power to delay or prevent the opening of a waste storage site or repository and to paralyze the nuclear industry while arguing that reasonable assurance of compliance with performance requirements has not been provided.

III. RISK IN THE FAR FUTURE

Even without taking into account the developments in science and technology, the estimated risk from the burial of high-level radioactive waste is extremely small. B. L. Cohen estimates that the (vitrified) high-level waste produced by one 1000 MW reactor in one year causes 0.018 eventual deaths, due to cancer.[5] In deriving this result he uses standard toxicity of high-level radioactive waste vs. time curves. He also uses conservative bounding assumptions to argue that an atom of average rock (or high level waste) has one chance in a trillion each year of being dissolved in water and ending up in a human stomach. Cohen also makes the very conservative assumption that all the waste in a repository will be exposed to water for 13 million years, at which time the remaining undissolved waste is assumed to be ingested. He also assumes that spent fuel is about 10 times as hazardous as vitrified high-level waste. With this assumption, the spent fuel discharged in one year from a 1000 MW reactor would lead to 0.18 eventual cancer deaths. For perspective, the air pollution from a coal plant producing the same amount of electricity would lead to 75 cancer deaths.[5] It is worth noting that all forms of energy generation involve risk and risk due to nuclear energy is low on the list.

Assuming that a 1000 MW reactor discharges 35 MT of spent fuel per year and that a repository holds 70,000 MT of spent fuel, we can conclude that the risk is 2.8×10^{-5} cancer deaths per year over a 13 million year period. This amounts to about an 18-day loss of life expectancy (LLE). The dose allowed by 10CFR63, 25 mrem per year, leads to 6.5×10^{-6} cancer deaths per year, or a loss of LLE of about 4 days. There are good arguments that these values should be reduced to even lower levels. The above estimates of cancer fatalities assume a linear no-threshold dose response. That is, half of any dose gives half as many cancer fatalities no matter how small the dose or dose rate. There is a significant body of literature that argues that this is not a valid assumption.[6]

More accurate estimates for the specific site at Yucca Mountain lead to the conclusion that the repository will have essentially no impact. The DOE Viability Assessment states, "The performance assessment for the preliminary design, though subject to uncertainties, indicates that for 10,000 years after the repository is closed, people living near Yucca Mountain would receive little or no increase in radiation exposure."[7]

The risk from the burial of high-level nuclear waste, even the risk estimated by very conservative bounding arguments, is far lower than everyday risks to which society is exposed. For example, the LLE due to many everyday risks is significantly greater.

Table 1. Loss of Life Expectancy[5]

Activity	LLE (days)
Radon in homes	35
Air Pollution	80
Fifteen Pounds Overweight	450
Being male (vs. female)	2800
Living in poverty	3500

It should be noted that although the risk due to the disposal of nuclear waste is extremely small, it is "significant" because it is perceived to be significant by the public, and herein lies the problem. The perceived risk coupled with the opportunity to challenge the compliance with the long-term requirements has led to costly delays in the U.S. repository program.

IV. ADVANCES IN SCIENCE AND TECHNOLOGY

The last few decades have seen tremendous advances in science and technology. A few examples suffice to make the point.

- Commercial satellite image resolution has gone from 80 meters in 1972 to 30 meters in 1982, to 10 meters in 1986, to 6 meters in 1995. It is likely that one-meter resolution will be available before long.[8]
- The speed and memory of computers have increased by over three orders of magnitude in three decades, while computers have become smaller and cheaper. Similar advances in software magnify these advances in hardware.
- Dramatic advances have been made in genetic engineering, microsurgery, artificial implants, human transplants, cloning, and other areas of bioscience and medicine.

It is worth noting that the rate of progress in the above and other areas has been much faster than linear as a result of increased availability of information and data, communications, collaboration, and synergy.

Continued progress in science and technology in the next 100 to 1000 years will reduce the already small risk attributed to the disposal of spent fuel and nuclear waste. The assumed risk from drilling for water near a repository will almost certainly vanish. Significant institutional and technological efforts are already underway today to conserve, clean up and reuse water. These along with the progress in obtaining more economical desalinated water will undoubtedly remove any incentive to drill for water in the desert, near a repository. Better and more economical water supplies will soon be essential for development and stability in many parts of the world. These are important incentives that will not be ignored.

Advances in remote sensing could facilitate monitoring nuclear waste repositories. It is planned that a repository will remain open for at least fifty years after the emplacement of the waste. During this time it would be possible to install monitors. Foreseeable progress in detection and data transmission could confirm the integrity of the waste in the repository for a long time. Advances in computing and modeling will allow improved forecasting of geologic events and better prediction of nuclear waste system performance. Advances in drilling, water treatment, etc. could make remediation simpler, cheaper and more effective if necessary.

Advances in medicine in the next 100 to 1000 years will almost certainly result in effective prevention, treatment, or cure of cancer. Newspapers and magazines contain ample anecdotal evidence that cancer therapy is already making great progress.[9] Medical statistics confirm this notion. For example, 25 years ago childhood leukemia was essentially a death sentence, with a survival rate of about 4%. Today the survival rate is over 80 %.[10] Progress has not been limited to leukemia. Important improvements have been made in diagnosing and treating for all forms of cancer. Survival rates for some forms of cancer that could be related to ingested radionuclides are shown below.

Table 2. Survival Rates (%) in the U.S.[11]

Site	'60-'63	'86-'93
Colon	43	63
Rectum	38	61
Stomach	11	19
Urinary Bladder	53	83
All sites	39	60

It is sometimes argued that we cannot depend on the progress of science and technology to protect future generations from the hazard of a nuclear waste repository. In fact this hazard depends on society losing track of the repository location. The short rejoinder is that if the repository information is lost, the society, or what's left of it, will have much more pressing problems than those associated with nuclear waste. The cause of loss of information, e.g. melting ice caps, ice age, nuclear war, comet strike, etc., will kill more people and cause more disruption and dislocation than all nuclear waste in a repository. More generally, if science and technology do not progress in a number of important areas, e.g., the development of energy, food and water supplies, tensions will be certain and wars will be likely. In any case nuclear waste would not be the major concern of such a future society.

V. THE COST OF CONSERVATISM

Conservative requirements for the far future have a costly impact today. Lack of certainty in predictions for geologic and hydrologic conditions and waste migration in the far future have led to more studies, changed policies, and postponed decisions. Lack of focus, leadership, and skilled management in the face of these difficulties has led to unnecessary delays and costs. Delays in implementing a plan for the disposition of spent fuel and nuclear waste result in delays in expanding use of nuclear power. This, of course, is the aim of many who demand a "permanent solution to the problem of nuclear waste." Delaying the deployment of nuclear power, especially in the developing world will likely result in increased degradation of the environment and a lower world standard of living, which will have a cost in lives.

A "permanent solution" is a psychological, rather than a technical, economic, or ethical imperative. It is worth noting that we do not have or require a similar type of permanent solution for the fly ash and effluents resulting from burning coal. It is often claimed that such a solution is necessary to discharge our responsibilities to future generations. This is not a compelling argument for many reasons. First, other solutions, such as monitored retrievable storage will protect future generations in all but extreme catastrophic scenarios. Storage of spent fuel would also give future generations the options for reuse or alternative disposal schemes. Second, air and water quality, and global warming are more pressing issues than nuclear waste for the next few generations, which are just as important as generations 10,000 years in the future. Finally, it is claimed that we must not burden future generations with nuclear waste solutions that require their attention. However, we do not seem to worry about burdening future generations with debt. Reducing the national debt for future generations would allow them flexibility to deal with nuclear waste and other issues as they see fit. This flexibility will save more lives than money spent on trying to prove the safety of permanently waste disposal.

Proving compliance with long-term requirements for nuclear waste disposal, which ignore the inevitable progress of science and technology, consume resources that could be used to save lives today and in the future. Costly law suits, political compromises, etc., use capital that could be spent on education, medical research and care, and investment to reduce the national debt. Studies[12] indicate that more lives could be saved by redirecting our resources. It is sometimes claimed that the funds for permanent disposal are not fungible in that they come from a tax on the production of electricity through the use of nuclear power and are for the purpose of disposing of nuclear waste. However, the effort to assure the performance in a far future where technology is unchanged consumes resources outside of the nuclear waste fund. Further, it is conceivable that Congress could decide to change the law and collect less for the nuclear waste fund and allocate more money for education, medical research, and debt reduction.

VI. SOLUTIONS

There is a widespread perception that we have a technologically difficult nuclear waste problem. The fact that the U.S. has not been able to progress toward geological disposal as planned is an institutional rather than technical problem, and there are institutional solutions to this problem. A solution could include changing the regulations. The period for the quantitative requirements could be changed to a few hundred, or perhaps a thousand years, reducing the opportunity to dispute and delay the disposition of spent fuel and high-level waste. For periods in the more distant future the requirements could be rewritten as goals. Of course, reasonable construction and fabrication specifications would be retained.

Taking into account the inevitable progress in science and technology discussed above, the already small risk presented by a geologic repository becomes vanishingly small. The risk then is not to human life but rather to the possible use of a resource. We should ask, "What is the probability that there will be useable amounts of water near the repository, and what would the negative impact be if it were not available for use because of the repository?"

In deciding what are appropriate requirements and how confidence in compliance should be demonstrated, we should look at other hazards and balance our efforts and resources. In particular we should ask how much protection and assurance as is required for the disposal of toxic heavy metals, such as mercury and lead. In doing so we should note that the threat posed by these types of materials is not reduced over time, whereas radioactive elements decay over time and become less hazardous. The U.S. and Canada have both begun to regulate isolation systems for some types of persistent toxic substances, such as pesticides. However, as a practical matter, use of some toxic metals, such as cadmium in batteries, is encouraged, and landfill disposal is the norm. Lined landfills are generally regarded as providing protection to the environment for 10-25 years, but retrieval needs to be completed well before 100 years has passed.[13] It is a waste of resources, and poor public policy to over regulate one hazardous activity and under regulate another. A risk-based balancing of requirements is needed

It appears that monitored retrievable storage is the current best alternative for spent fuel and high-level nuclear waste. Monitored retrievable storage would allow notice of any impeding hazard in time to overpack or reconstruct the waste package. Storage is safe and easily understood, and it preserves future options, including the recycling of spent fuel, or possibly unimagined uses for spent fuel and high level waste. In the future there will undoubtedly be more effective ways to dispose of waste that may be less expensive and less controversial. In any case, more and better information will be available for decision making. If necessary, so as overcome the restriction placed on the development of nuclear power by some States, monitored retrievable storage (surface, near surface, or underground) could be defined to be "permanent."

In summary, this paper has tried to point out: 1) Geologic disposal of spent fuel and high-level waste represents an insignificant risk compared to the everyday risks society is exposed to. 2) The regulatory requirements for disposal are based on flawed assumptions, are too conservative, and costly. 3) Because of the political and institutional difficulties, and the costs to overcome them, monitored retrievable storage is currently the best option for the disposition of spent fuel and high-level waste.

We should refocus our nuclear waste policy to provide for the safe disposition for nuclear waste, and spent fuel, for the next one hundred years, with periodic reevaluation of the options. Responsible action in this direction will engender the public confidence necessary for the safe, economical disposition of spent fuel and high-level waste.

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