United States General Accounting Office

GAO

Report to the Honorable
Pete Domenici, U.S. Senate

June 2000

RADIATION STANDARDS

Scientific Basis Inconclusive, and EPA and NRC Disagreement Continues

Contents

Abbreviations

DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
NRC	Nuclear Regulatory Commission

GAO

Accountability * Integrity * Reliability

United States General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

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June 30, 2000

The Honorable Pete Domenici
United States Senate

Dear Senator Domenici:

As the cold war came to a close, the United States shifted its focus from producing nuclear weapons to cleaning up its nuclear weapons production facilities. The Department of Energy (DOE), which manages the U.S. nuclear weapons program, is now cleaning up over a dozen major weapons production sites around the country. In addition, the nation's nuclear power industry is starting to decommission over 100 commercial nuclear power plants located in 31 states, a task that will continue during the coming decades. Furthermore, DOE is determining the feasibility of constructing an underground repository to provide for permanently disposing of much of the nation's highly radioactive waste at Yucca Mountain, Nevada. Until a repository is operational, federal facilities and nuclear power plants across the country will continue to store their highly radioactive waste on-site.

What standards should be used to protect the public from the risks of exposure to low-level radiation remaining at these sites after the nuclear materials and wastes have been removed—or, in the case of Yucca Mountain, to protect the public from exposure to the buried waste—is a question for which two federal agencies share primary responsibility. The Environmental Protection Agency (EPA) issues generally applicable public radiation protection standards and administers the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), which governs cleanups of federal and nonfederal facilities. The Nuclear Regulatory Commission (NRC) issues implementing radiation protection standards as part of its mandate to regulate civilian sources of nuclear radiation, and it oversees the decommissioning of commercial nuclear facilities. The states may also be involved in radiation protection efforts under agreements with NRC for nuclear facilities within their jurisdictions. Finally, the National Academy of Sciences has a congressionally mandated role in recommending radiation protection standards for the Yucca Mountain repository.

Historically, EPA and NRC have sometimes differed over how restrictive U.S. radiation protection standards should be, as we reported in 1994.[1] These differences have implications for the pace and cost of federal facility cleanups and commercial decommissioning efforts, as well as for the design and potential development of the Yucca Mountain repository. Concerned about these issues, you asked us to examine the scientific basis for the agencies' radiation protection standards and the costs of implementing them. As agreed with your office, this report examines (1) whether the current U.S. radiation protection standards have a well-verified scientific basis, (2) whether federal agencies have come closer to agreeing on standards since we reported on this issue in 1994, and (3) how implementing these standards may affect the costs of nuclear waste cleanup and disposal activities. During our review, we examined many scientific studies and obtained the views of recognized scientists on the scientific basis of radiation standards. We focused mainly on differences in standards for Yucca Mountain and nuclear cleanup and decommissioning sites because they are prominent current examples of the debate about standards. In addition, the report includes a review, performed by a recognized expert in environmental radiation, of scientific research correlating naturally occurring (background) radiation levels in the United States and around the world with local cancer rates. This review was designed to determine whether the research results might have implications for setting radiation protection standards. (See app. I for a detailed discussion of our scope and methodology.)

Results in Brief

U.S. regulatory standards to protect the public from the potential health risks of nuclear radiation lack a conclusively verified scientific basis, according to a consensus of recognized scientists. In the absence of more conclusive data, scientists have assumed that even the smallest radiation exposure carries a risk. This assumption (called the "linear, no-threshold hypothesis" or model) extrapolates better-verified high-level radiation effects to lower, less well-verified levels and is the preferred theoretical basis for the current U.S. radiation standards. However, this assumption is controversial among many scientists. Some say that the model is overly conservative and that below certain exposure levels, there is no risk of cancer from radiation. Others say that the model may underestimate the risk. The research evidence is especially lacking at regulated public

[1] *Nuclear Health and Safety: Consensus on Acceptable Radiation Risk to the Public Is Lacking* (GAO/RCED-94-190, Sept. 19, 1994).

exposure levels—levels of 100 millirem a year and below from human-generated sources. Interest among scientists in obtaining a more conclusive understanding of the effects of low-level radiation has been evident in recent federally funded initiatives, including a reassessment by the National Academy of Sciences of the latest research evidence on the risks of low-level radiation, begun in the summer of 1998 and planned to conclude in 2001. Also, a 10-year DOE research program, begun in fiscal year 1999, has been specifically addressing the effects of low-level radiation within human cells, in part to help verify or disprove the linear model.

Lacking conclusive evidence of low-level radiation effects, U.S. regulators have in recent years set sometimes differing exposure limits. In particular, EPA and NRC have disagreed on exposure limits. Although we recommended as far back as 1994 that the two agencies take the lead in pursuing an interagency consensus on acceptable radiation risks to the public, they continue to disagree on two major regulatory applications: (1) the proposed disposal of high-level nuclear waste in a repository at Yucca Mountain and (2) the cleanup and decommissioning of nuclear facilities. Centrally at issue between the two agencies is groundwater protection. On the one hand, EPA applies community drinking water limits for radioactive substances to groundwater at nuclear sites, as a matter of water resource protection policy. Some of these limits are equivalent to fractions of a millirem a year. On the other hand, NRC includes groundwater and other potential contamination sources under a less restrictive limit of 25 millirem a year for all means of exposure,[2] an approach that conforms to internationally recommended radiation protection guidance. As applied in proposed standards for nuclear waste disposal at Yucca Mountain, EPA's groundwater approach has been criticized as technically unsupported by the National Academy of Sciences, which the Congress mandated to recommend standards for the repository. However, the Academy recognizes that EPA has the authority to establish a separate groundwater limit for Yucca Mountain, and EPA believes its groundwater protection approach for the repository to be technically justified. As applied to nuclear cleanup and decommissioning sites where both EPA and NRC may have jurisdiction, the two agencies' different regulatory approaches have sometimes raised questions of inefficient, conflicting, dual regulation. There has been little progress in finalizing a memorandum of

[2]These means of exposure, called "pathways" by specialists, include exposure through soil, water, and air.

understanding, encouraged by the House Appropriations Committee in August 1999, to resolve EPA's and NRC's conflict about cleanup standards. Given their historical differences, EPA and NRC may not easily agree on groundwater protection standards for Yucca Mountain or on their respective regulatory roles relating to nuclear cleanup and decommissioning sites. This report contains a matter for congressional consideration suggesting that, in such a situation, the Congress may wish to help resolve the agencies' disagreement.

The costs of implementing different radiation standards vary, depending on the standards' restrictiveness. Generally, the costs increase as the standards become more restrictive. Comprehensive estimates of overall costs to comply with current and prospective standards were unavailable, but these costs could be immense, considering that federal agencies expect to fund hundreds of billions of dollars in nuclear waste disposal and cleanup projects over many years in the future. According to DOE's and NRC's analyses of cleanup options for individual sites, costs per site can be many millions of dollars higher to comply with more restrictive standards than less restrictive standards, as might be expected. For example, a 1995 DOE analysis of cleanup options for plutonium-contaminated test ranges at the Nevada Test Site estimated $35 million in costs to achieve a 100-millirem-a-year-level, over three times as much to achieve a 25-millirem-a-year level, and over six times as much to achieve a 15-millirem-a-year level. Finally, the analysis showed costs that were over 28 times higher to achieve a 5-millirem-a-year level, illustrating that compliance costs accelerate rapidly to achieve the most restrictive protection levels.

We presented a draft of this report to NRC, DOE, and EPA for comment. NRC found the report to be fundamentally sound, and DOE found it to be factual and balanced. EPA disagreed with the report's conclusions, particularly our conclusion that there has been little progress on the finalization of a memorandum of understanding to resolve EPA's and NRC's conflict about cleanup standards. However, although the two agencies are developing such a memorandum, they have had long-standing differences, and we question whether their latest efforts will resolve these differences without congressional intervention. All three agencies provided technical comments on the report. In response to the comments received, we made some changes to the report's presentation.

Background

Nuclear radiation can be generally categorized as either low-level or high-level radiation. The low-level range includes exposures up to about 10,000 total millirem,[3] although the term commonly is used to refer to exposures of a few hundred millirem or less.[4] The lower portion of the low-level range includes natural background radiation levels, and the lowest portion of this range includes public exposure levels regulated under various U.S. radiation standards, as shown in appendix II.[5] Natural background radiation levels vary around the world, from below 100 millirem of exposure a year in some places to several hundred millirem a year in others, with even higher levels recorded in "hot spots." In the United States, average natural background radiation exposure is about 300 millirem a year. In addition, medical practices, such as X-rays and nuclear medicine, and industrial nuclear operations contribute average public exposures of about 50 millirem a year and 0.1 millirem a year, respectively. Radiation from within one's own body, largely from naturally present radioactive potassium, contributes almost 40 millirem a year, on average. As shown in appendix II, regulatory public exposure limits vary from a few millirem a year up to 100 millirem a year. At these levels, radiation is only one of many environmental and biological events (such as heat) that may alter (mutate) cell structure, and low-level radiation is commonly considered to be a relatively weak source of cancer risk.[6] To counter these cellular-level mutations, the human body has active repair processes, although these processes are not entirely error-free, and their relevance to human cancer risk remains unclear. Should a radiation-caused cancer develop in one or more cells, the process may take years, and the source of the cancer will be verifiable only in exceptional cases, given the current limited

[3]A millirem is a commonly used unit of measurement of the biological effect of radiation. The radiation from a routine chest X-ray is equivalent to about 6 millirem.

[4]Above about 30,000 total millirem, radiation exposure is a well-known cause of cancer. Instantaneous (or short-duration) exposures of about 200,000 total millirem can cause blood cell changes, infections, and temporary sterility. Short-duration exposures above about 400,000 total millirem can cause death within days or a few weeks and are associated with catastrophic nuclear accidents or atomic bomb blasts.

[5]U.S. worker protection standards limit annual exposures to 5,000 millirem. See app. II.

[6]About 187,000 spontaneous cell-altering events occur daily in each human cell. Low-level radiation exposures increase the number of such events by a small fraction—about 1 percent. There is evidence that the type of damage done by such radiation has a higher probability of resulting in DNA misrepair than the type of damage done by other normally occurring cell-altering events.

understanding of how cancer develops. Although nearly one in four persons in the United States dies of cancer from all causes, low-level radiation presumably accounts for a very small fraction of these cancers, if any. However, the fraction cannot be quantified.

Federal agencies, and in some instances states, administer U.S. radiation standards. EPA and NRC administer the majority of the federal standards. EPA issues environmental radiation protection standards as mandated under Presidential Reorganization Plan No. 3 of 1970. NRC issues standards as part of its mandate to regulate civilian sources of nuclear radiation, under the Atomic Energy Act. (Under the same act, DOE has issued public and worker exposure limits applicable on-site at the agency's nuclear installations.) Both EPA and NRC have regulatory roles related to nuclear waste disposal and nuclear site cleanup and decommissioning. For example, under the Energy Policy Act of 1992, both have roles at the proposed Yucca Mountain repository in southern Nevada. The proposed function of the repository is to receive and dispose of high-level waste from DOE sites and commercial power plants around the country. EPA has the role of issuing standards to protect the public from releases of radioactive materials from the facility, and NRC has the role of issuing technical requirements and criteria and licensing the facility. Under the act, exposure limits in NRC's final technical requirements and criteria are to be consistent with the limits in EPA's final public protection standards. DOE's role at Yucca Mountain will be as the developer and prospective operator of the repository, and the Department is pursuing the goal of deciding in 2001 whether to recommend the site to the President as suitable for nuclear waste disposal. Also involved in Yucca Mountain oversight are expert advisory bodies, including the Nuclear Waste Technical Review Board and the National Academy of Sciences, which was mandated under the Energy Policy Act of 1992 to recommend standards for the repository. In regard to nuclear cleanup and decommissioning activities, both EPA and NRC have mandated roles: EPA administers Superfund, the legislation that governs cleanups of federal and nonfederal facilities, and NRC regulates the decommissioning of over 100 active commercial nuclear power plants, as well as other commercial nuclear facilities, under the Atomic Energy Act.[7,8]

Our September 1994 report on radiation protection issues found that U.S. radiation standards reflected a lack of federal agency consensus on acceptable radiation risk to the public, as well as a lack of interagency coordination on standards. Among the reasons we found for the lack of consensus were differences in agencies' historical missions and legislative mandates, as well as differences in agencies' regulatory strategies, particularly in those of EPA and NRC. For example, EPA has historically in many cases implemented a risk-based radiation protection approach, under which the agency addresses individual contamination sources, coregulates chemicals and radioactive substances, and protects both human health and environmental resources.[9] In accordance with its tradition of regulating chemicals, EPA has generally set a risk of 1 in a million that an individual will develop cancer in a lifetime as a goal for remediation and has considered a risk of greater than 1 in 10,000 to be potentially excessive. EPA's approach has been described as "bottom up," setting a relatively restrictive risk goal to be pursued through the best available technology—but allowing less restrictive limits in site-specific situations. In contrast, NRC favors a dose-based, radiation-specific protection approach that focuses on human health protection.[10] NRC's protection strategy has been

[7]Superfund regulations call for, among other steps, the development of cleanup alternatives through a remedial investigation, the finalization of applicable cleanup requirements, and a formal record of decision on an agreed cleanup level, after which cleanup is conducted. Decommissioning involves the removal of all radioactive components and materials from the facility and the cleanup of radionuclides to NRC's standards (10 C.F.R. 20).

[8]The coordination of federal radiation protection issues is the responsibility of the federal Interagency Steering Committee on Radiation Standards, and coordination among states is the responsibility of the Conference of Radiation Control Program Directors. In addition, authoritative national and international technical organizations make recommendations on radiation protection issues, including the congressionally chartered U.S. National Council on Radiation Protection and Measurements, the International Commission on Radiological Protection, and the United Nations Scientific Committee on the Effects of Atomic Radiation.

[9]EPA's protection approach draws, in part, on experience with regulating thousands of different chemicals, many of which pose risks that are generally thought to be even less well understood than radiation risks. These chemicals may or may not exist naturally in the environment.

[10]NRC's approach (with which DOE generally concurs) draws on experience in estimating radiation-specific risks, within an internationally recommended radiation dose limitation and risk assessment framework. The framework takes into account that radiation exists naturally in the worldwide environment.

described as a "top down" approach. Compared with EPA, NRC sets a relatively less restrictive dose limit but reduces doses (and risks) well below the limit in site-specific situations where the reductions are "reasonably achievable."[11]

U.S. Public Radiation Protection Standards Lack a Conclusive Scientific Basis

The standards administered by EPA and NRC to protect the public from low-level radiation exposure do not have a conclusive scientific basis, despite decades of research. These standards are based on a hypothetical model of low-level radiation effects. The model, derived from studies of large populations (in the tens of thousands) exposed to radiation, extrapolates better-verified high-level radiation effects to lower, less well-verified levels. The standards protect at annual millirem levels considerably lower than the better-verified levels. According to a consensus of scientists, there is a lack of conclusive evidence of low-level radiation effects below total exposures of about 5,000 to 10,000 millirem. The model under which these effects are assumed, lacking conclusive evidence, is called the "linear, no-threshold" hypothesis or model. According to this model, even the smallest radiation exposure carries a quantifiable cancer risk. The model, which has been endorsed by national and international radiation protection organizations and used for many years as a preferred model in regulating low-level radiation, is a fundamental basis for U.S. radiation standards. There is interest among scientists in obtaining more conclusive evidence of radiation effects, and a DOE research program that is examining cellular low-level radiation effects may eventually help to develop a better understanding of the cellular processes of radiation cancer causation.

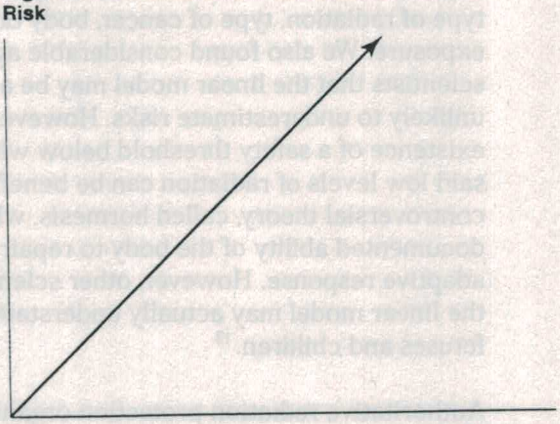
Low-Level Radiation Effects Are Assumed for Regulatory Purposes

Conclusive evidence of radiation effects is lacking below a total of about 5,000 to 10,000 millirem, according to the scientific literature we examined and a consensus of scientists whose views we obtained. At these

[11]NRC's 25-millirem-a-year dose limit is equivalent to 1 chance in about 1,000 of a fatal cancer over a 70-year lifetime, using a commonly accepted dose-risk conversion factor and assuming the linear model of radiation effects holds.

levels, authoritative bodies have estimated radiation risks through complex modeling of the available data,[12] and regulators have assumed that even the smallest radiation exposure carries a risk. This assumption is commonly referred to as the linear, no-threshold hypothesis or model. Extrapolated mainly from high-dose effects reported for Hiroshima and Nagasaki survivors, the linear model assumes that radiation health effects are proportional to exposure. As figure 1 shows, the model uses a straight line to extrapolate risks all the way down to zero. From zero upward, the model assumes that as exposure doubles, risk doubles, and that no entirely risk-free exposure level or threshold exists.

Figure 1: The Linear, No-Threshold Model of Low-Level Radiation Effects



Radiation protection organizations such as the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection have historically endorsed the model, and U.S. regulators have used it as a preferred, plausible model, but it is controversial. On the one hand, the model is widely considered to be a useful, relatively mathematically simple working hypothesis that may be

[12]For example, a 1990 study by a National Academy of Sciences committee, called BEIR V, estimated that, at the 90-percent statistical confidence interval, out of 100,000 adults exposed to 100 millirem a year of radiation over a lifetime, anywhere from 410 to 980 men and 500 to 930 women might die of cancer caused by the exposure. This confidence interval assumes the validity of the linear model and reflects the uncertainty of inputs to the model.

conservative—that is, it may not underestimate risks. Regulators make use of the model in doing risk assessments, regulatory impact analyses, cost-benefit analyses, and other studies to support their decision-making. In using the model, they are able to estimate risk reductions and hypothetical lives saved from regulating at a given exposure level. On the other hand, many scientists question the validity of the model. The consensus view we encountered is that the research data on low-level radiation effects are inadequate either to establish a safety threshold or to exclude the possibility of no effects. Scientists we contacted and scientific literature we examined generally did not indicate that any one model clearly best fit the overall data. Instead, there was evidence that any of several models may "fit." (See app. III.) Some researchers also said low-level radiation effects are likely too complicated and variable to be expressed in a single model. There is evidence that the relationship may vary in individuals, and with the type of radiation, type of cancer, body organs exposed, sex, and/or age at exposure. We also found considerable agreement among regulators and scientists that the linear model may be a conservative "fit" to the data, unlikely to underestimate risks. However, some said the data support the existence of a safety threshold below which there are no risks, and others said low levels of radiation can be beneficial to health. This is a highly controversial theory, called hormesis, which is in part based on the documented ability of the body to repair cell damage—referred to as adaptive response. However, other scientists pointed to studies indicating the linear model may actually understate radiation risks, especially to fetuses and children.[13]

Authoritative radiation protection organizations and committees have given the linear model a qualified endorsement. For example, in 1990, a committee of the National Academy of Sciences, the Biological Effects of Ionizing Radiation Committee (BEIR V), reported that the linear model was not inconsistent with the available research data. According to the committee's report, at low radiation exposures, risks either less or greater than linearity—and the existence of a threshold in the low-level dose range—cannot be excluded, and "the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out. At such low doses, it must be acknowledged that the lower limit of the range of uncertainty in the risk estimates extends to zero." In addition, a 1994 report of the United Nations Scientific Committee

[13]There is evidence of mental retardation linked to fetal exposure to low-level radiation. Age at time of exposure appears to be an important determinant of cancer risk from radiation.

on the Effects of Atomic Radiation (UNSCEAR) stated that "there are theoretical reasons based solely on the nature of DNA damage and repair to expect that cancer can occur at the lowest doses without a threshold in the response, although this effect would perhaps not be statistically demonstrable."[14] Despite the linear model's unproven and controversial status among scientists, some scientists said the model is so well accepted that it could only be superseded on the basis of overwhelming contrary evidence.

Research Efforts to Verify Low-Level Radiation Effects Are Ongoing

Two types of important research into low-level radiation effects have been conducted. One type of study painstakingly follows the long-term health of individuals in large populations exposed to radiation, seeking statistically significant patterns of elevated cancer risks from the radiation exposures. These are called epidemiological studies. Another type of study subjects animals or tissue or cell cultures to radiation, seeking biological evidence of radiation effects. These are called radiobiological studies.

Epidemiological studies may never conclusively prove or disprove the linear model, according to some scientists. Epidemiological studies have been a key basis for the linear model, including the research evidence accumulated on over 85,000 Japanese survivors of the Hiroshima and Nagasaki bomb blasts. The study, conducted by the international Radiation Effects Research Foundation, has well established the effects of radiation at high exposure levels, and scientists have extrapolated this relationship to the low-level radiation range as well—with considerable inherent uncertainty.[15] However, some scientists have questioned the project's results, asserting among other concerns that the basic estimates of the Hiroshima and Nagasaki doses (and their neutron component, for example) still need to be reevaluated, even after decades of effort devoted to determining these doses.

As noted, epidemiological studies require large study populations for the research results to be statistically powerful. Epidemiologists consider two

[14] The British National Radiation Protection Board similarly maintains, in consideration of relevant cellular and molecular data, that the weight of evidence falls decisively in favor of the thesis that for a majority of common human tumors, low-dose and low-dose-rate cancer risk rises as a simple function of dose with no threshold.

[15] According to one expert, extrapolating effects from high exposures to low exposures equivalent to natural background radiation levels is more guesswork than science.

types of epidemiological studies—analytic or ecologic. Analytic studies either compare individuals who have been exposed to radiation to individuals who have not been exposed and determine if there are subsequent differences in their health status (cohort studies) or compare individuals who have a disease to those who do not to determine if there were differences in the past exposures of the two groups (case control studies). Ecologic studies rely on regional data on disease and radiation levels, instead of individual data, and are considered to be less reliable than analytic studies. Analytic and ecologic studies have attempted to correlate regional natural background radiation levels with regional cancer rates at locations in the United States, Europe, Asia, Brazil, Iran, and other places. A premise related to such studies is that, if the linear model holds, cancer rates should be higher at locations where natural background radiation levels are significantly higher. With the help of an expert consultant, we examined 82 studies, which generally found little or no evidence of elevated cancer risks from high natural background radiation levels. A large number of studies reported a lack of evidence of cancer risks, some others reported evidence of slightly elevated risks, and some others reported evidence of slightly reduced risks. Overall, the studies' results are inconclusive, but they suggest that at exposure levels of a few hundred millirem a year and below, the cancer risks from radiation may be either very small or nonexistent. (See app. IV.)

Radiobiological studies, particularly molecular studies, may eventually develop more conclusive scientific evidence of low-level radiation effects than epidemiological studies, according to scientists. Past radiobiological research has helped to establish, among other evidence, the genetic effects of radiation and its effects on individual body organs. Recently, there has been interest in research into the cellular processes through which radiation causes cancer, in part in relation to progress in human genome research in the 1990s.[16] Researchers have been obtaining a better understanding of specific phenomena such as DNA damage and repair, chromosomal instability, so-called "bystander" effects on neighboring cells, and cellular adaptation to exposures. Researchers are looking into such cellular processes for biological signs (or "biomarkers") of radiation cancer causation. Several stages are apparent in the development of radiation-caused cancer: DNA damage, misrepair, cancer initiation, cell proliferation, and tumor promotion (with subsequent malignant transformation). To date, the first stage in the process is better understood than the long-term second

[16]Such research focuses on cells' nuclei, where DNA is located.

stage. Since fiscal year 1999, DOE has funded a research program targeting the biological effects of low-level radiation at the cellular level, with total funding of almost $220 million projected over 10 years. The program is considered unique in that it is designed specifically to better validate the effects of very low levels of radiation in areas such as cells' response to radiation damage, thresholds for low-dose radiation effects, and features distinguishing radiation-caused cell damage from damage from causes internal to the cell. Many scientists and regulators we interviewed said this type of research could eventually help to determine more conclusively the effects of low-level radiation and their potential link to cancer causation.

In October 1998, the National Academy of Sciences contracted to reassess the linear model and risk estimates for low-level radiation, at the request of U.S. regulators, including EPA, NRC, and DOE. The regulators, acting through the Interagency Steering Committee on Radiation Standards, concluded that enough research progress had been made in the 1990s to warrant the study. The Academy last did such an assessment in 1990, called BEIR V. The latest assessment, called BEIR VII, is to be completed by 2001.[17] High expectations have been set for the BEIR VII committee, reflecting the scientific controversy surrounding the linear model and low-level radiation effects. For example, in requesting the effort, EPA, DOE, and NRC asked the committee to focus on areas the agencies do not believe were emphasized in the previous BEIR V effort. EPA asked the committee to provide a clear indication of the weight of evidence for risks at low doses and dose rates and to carefully assess the sources of any inconsistencies in the results from different epidemiological studies. DOE asked BEIR VII to consider epidemiological studies on nuclear workers, and NRC asked the committee to focus especially on evidence of radiation effects at the lowest portion of the low-level radiation range, at levels where regulators set radiation standards, and to consider evidence of hormesis. Also, the committee is committed to fully assessing all pertinent research data, not just the data that have been traditionally influential, such as the Hiroshima and Nagasaki data. Because of its broad focus, the BEIR VII assessment could produce instructive results, but some agency officials and scientists said the amount of new research data available might not be sufficient to lead the committee to either fully validate or disprove the linear model. An EPA official said he expected the BEIR VII work to support the continued use of the linear model for regulatory purposes.

[17]BEIR VI was a 1999 Academy assessment of risks from radon.

EPA and NRC Continue to Disagree on Major Radiation Standards for Public Protection

We reported in 1994 that federal agencies' radiation standards reflected a lack of consensus on acceptable risk to the public. Today, this situation persists, and EPA and NRC, the principal federal radiation standard-setting agencies, continue to disagree significantly on regulatory approaches and standards related to groundwater protection. Two major instances of their disagreement are proposed standards for the prospective Yucca Mountain high-level-waste repository and standards for the cleanup and decommissioning of federal and commercial nuclear facilities. For these applications, EPA favors both (1) a public protection limit of 15 millirem a year from all radiation sources through all means of exposure—called "all pathway" protection by specialists—and (2) extra protection of groundwater resources under sites, at limits originally set for community drinking water systems, equivalent to 4 millirem a year. Alternatively, NRC favors a single 25-millirem-a-year all-pathway public protection limit, within which groundwater is a potential pathway. [18] This disagreement has complicated planning for the prospective Yucca Mountain high-level waste repository, on which a national decision is to be made in 2001, as well as day-to-day planning for facility decommissioning by commercial nuclear operators licensed by NRC. In both of these cases, it remains to be seen whether EPA and NRC can resolve their differences or whether the Congress will need to intervene.

EPA and NRC Have Proposed Different High-Level-Waste Disposal Standards

The disagreement between EPA and NRC on groundwater protection is reflected in differences in the radiation standards set by the two agencies but appears most notably in the debate over proposed draft standards for the Yucca Mountain, Nevada, high-level-waste repository. Radiation standards are an important part of the ongoing debate about the future of the planned facility. Both EPA and NRC issued proposed radiation protection standards for the repository in 1999, NRC in February and EPA in August. The agencies differ on proposed all-pathway limits (15 millirem a year versus 25 millirem a year), and especially on extra groundwater protection. The groundwater issue at Yucca Mountain relates to differences in the two agencies' overall resource protection policies, as well as technical details. EPA's approach reflects its attempt to implement a

[18] EPA's approach includes various levels of acceptable risk, from 1 chance in about 2,000 to less than 1 chance in about a million of a fatal cancer over a 70-year lifetime. NRC's all-pathway approach involves a level of acceptable risk of 1 chance in about 1,000 of a fatal cancer over a lifetime. These calculated risks are based on a commonly used dose-risk conversion factor, assuming the linear model holds.

consistent policy, across various standards, of protecting groundwater as a national resource, in line with community drinking water standards established in regulations under the Safe Drinking Water Act. (According to EPA, the policy is based on preventing pollution before it occurs. If pollution has occurred, the polluter should be responsible for the costs of cleanup.) On the other hand, NRC believes its all-pathway approach is fully protective of human health at Yucca Mountain and elsewhere. In the Commission's view, EPA's drinking water standards were not originally intended for an application such as Yucca Mountain, and the Commission questions EPA's technical basis for proposing extra groundwater protection.[19,20]

NRC has been joined in its views by DOE and some others who have commented on EPA's proposed Yucca Mountain standards, including the National Academy of Sciences. The Academy has questioned the technical basis for EPA's extra groundwater protection approach. Specifically, the Academy, together with NRC, DOE, and other commenters, has asserted, first, that EPA has not provided a technical rationale for its approach. By contrast, according to these commenters, NRC has a technically based rationale for its approach that is in accord with internationally recommended radiation protection practices. Second, the Academy and others have pointed out that the drinking water concentration limits to be applied to groundwater at the repository are outdated, reflecting doses and risks that are inconsistent. These limits consist of dozens of numerical maximum contaminant levels for radionuclides, expressed in picocuries per liter, which reflected consistent doses and risks when they were

[19]The agencies also disagreed on low-level waste disposal standards in the mid-1990s. Current low-level waste standards consist of NRC's 25-millirem-a-year all-pathway limits that date from 1983. In 1994, EPA considered issuing its own standards, reflecting 15-millirem-a-year all-pathway protection, plus extra groundwater protection to drinking water standards. At the time, DOE estimated over $300 million in added annual costs if its disposal sites and commercial disposal sites were required to comply with the approach EPA was considering.

[20]In addition, in 1994, EPA issued transuranic waste disposal standards for the Waste Isolation Pilot Project in southeastern New Mexico (40 C.F.R. 191) that include 15-millirem-a-year all-pathway limits, plus extra groundwater protection to drinking water standards. NRC expressed concerns about the groundwater protection standards but concurred with them because on-site groundwater was not an issue in EPA's project certification process—the aquifer was brine. Transuranic waste is tools, rags, laboratory equipment, and other items contaminated with radioactive elements, mostly plutonium.

established in regulations implementing the Safe Drinking Water Act of 1976.[21] These limits are outdated under the latest risk estimation methods.

In particular, the Academy, in its congressionally-mandated role of recommending reasonable standards for protecting health and safety at the repository, has questioned EPA's groundwater protection approach for Yucca Mountain. The Academy did not propose separate groundwater protection standards for the repository in its own technical recommendations for the facility, which were issued in 1995. The Academy's November 1999 comments on EPA's draft standards directly opposed such an approach, calling it "scientifically unsupported," adding little or no public health benefit.[22] According to the Academy, EPA has the authority to establish a separate groundwater limit for Yucca Mountain but has not presented a technical rationale for doing so. In addition, NRC and DOE have commented that EPA has not done a comprehensive analysis of the health benefits and costs of its groundwater approach for Yucca Mountain. EPA has issued a draft regulatory impact analysis to accompany its draft Yucca Mountain standards, in accordance with Executive Order 12866, which calls for such an analysis if the regulatory action is significant (for example, raises novel legal or policy issues). However, the draft regulatory impact analysis was limited in scope (stating that data were lacking for a fuller discussion), and the document did not analyze the specific impact of EPA's groundwater protection approach for the repository.

EPA recognizes that the drinking water contamination limits that are to be applied at the repository are not scientifically up to date. They are based on 1970s-era methods of radiation dose estimation, which have been superseded. The limits were originally intended to be equivalent to 4 millirem a year of exposure. However, under updated dose estimation methods, they no longer reflect 4 millirem a year. Instead, using a commonly accepted dose conversion factor, they reflect varying annual millirem levels and acceptable risks, and some reflect millirem levels up to a thousand times lower than average U.S. natural background radiation levels. A few of the limits are equivalent to well above 4 millirem a year, but

[21]Under 40 C.F.R. 141, annual concentrations of beta particle and photon activity sources are limited to no more than a total body or internal organ dose equivalent of 4 millirem a year. See app. II.

[22]On the other hand, the Academy found the magnitude of EPA's proposed 15-millirem-a-year all-pathway limit to be consistent with the Academy's own recommendations.

many are equivalent to fractions of a millirem a year.[23] NRC has commented that because groundwater is expected to be the dominant exposure pathway at Yucca Mountain, these limits will be the de facto overall protection standards for the repository.

According to EPA officials, the agency's proposed standards and groundwater protection approach for Yucca Mountain are justified on policy grounds and are technically justifiable as well. The agency has applied drinking water standards to groundwater at the repository, EPA officials said, because it desires to protect groundwater as an environmental resource (for drinking water and irrigation needs) in a region where the population has been growing quickly. In addition, the agency has a general policy of coregulating chemicals and radionuclides in groundwater, and EPA officials said the standards for Yucca Mountain should be in accord with this policy. EPA officials agreed that the agency has not done a comprehensive analysis of the health benefits and costs of the agency's groundwater approach for Yucca Mountain, but they believe their regulatory approach has fully addressed the pertinent overall technical issues related to setting radiation protection standards for the site. They said they are developing an expanded regulatory impact analysis to accompany their final standards, which will not constitute a specific technical rationale for their extra groundwater protection approach but will address technical and cost issues related to the implementation of their standards, as the Academy recommended.

While recognizing that the drinking water concentration limits to be applied at Yucca Mountain are out of date, reflecting inconsistent doses and risks, EPA officials said the agency is in the process of updating the limits and expects to complete this effort by the fall of 2000. They said that if the final Yucca Mountain standards are issued before then, the updated limits will be incorporated into them. The officials noted that under a "no backsliding" provision of the 1996 Safe Drinking Water Act Amendments, any updated drinking water standards for radionuclides must maintain

[23]For example, the limit for Iodine 129, considered a benchmark among the various limits for Yucca Mountain, is 1 picocurie per liter, or about 0.2 millirem a year; the limit for Nickel 63 is 50 picocuries per liter, or about 0.02 millirem a year, and the limit for Tritium is 20,000 picocuries per liter, or about 0.9 millirem a year. In addition, the limits reflect acceptable lifetime risks ranging anywhere from less than 1 chance in a million to more than 1 chance in 2,000 of a person dying from the exposure, using a commonly accepted dose-risk conversion factor and assuming the linear model holds. EPA points out that most limits fall within its acceptable risk range of 1 chance in about 10,000 to 1 chance in about a million of a person getting cancer from the exposure.

equal or greater levels of public health protection. According to EPA, this provision precludes the agency from raising any of the concentration limits, even in attempting to achieve greater uniformity in doses or risks.[24] A draft version of the proposed new limits indicates that EPA may not change any of the limits.[25]

As EPA and NRC prepare to issue final standards for Yucca Mountain, it is not evident that the two agencies and the Academy will agree on appropriate groundwater protection standards for the repository. If they do not agree, EPA's final Yucca Mountain standards, expected to be issued in the summer of 2000, will lack a degree of technical consensus that would add to their credibility and acceptability. Aware of the conflict between EPA and NRC over standards for Yucca Mountain, the Congress, in March 2000, passed legislation retaining EPA's standard-setting authority while (1) allowing the Academy and NRC to report to the Congress any major disagreements they may have with EPA's final standards and (2) delaying the issuance of final standards for Yucca Mountain until June 2001. On April 25, 2000, the President vetoed the bill, in part because it would have limited EPA's authority to issue radiation standards, and on May 2, 2000, the Senate upheld the veto.

EPA and NRC Have Issued Different Standards and Guidance for Nuclear Site Cleanup and Decommissioning

Both EPA and NRC developed nuclear site cleanup and decommissioning standards in the 1990s, attempting to facilitate the massive national effort to clean up nuclear contamination at many federal and commercial nuclear sites—including DOE's nuclear weapons complex and commercial nuclear power plants licensed by NRC —that are closing down after decades of operations. In 1995, EPA drafted cleanup standards reflecting the agency's groundwater protection approach, which includes 15-millirem-a-year all-pathway protection, plus separate groundwater protection to drinking water standards. However, the agency withdrew these standards in 1996, before they were finalized, after other agencies objected to them. Subsequently, in 1997, EPA implemented the same approach through

[24]Another technically related groundwater issue is EPA's prospective choice of a groundwater scenario for Yucca Mountain, including the point of enforcement (at or how near to the repository boundary) and appropriate estimated groundwater flow volume. DOE and NRC officials said a very conservative scenario could severely complicate DOE's efforts to do detailed, refined groundwater analysis for the site.

[25]According to EPA, the new limits are to be based on acceptable risks instead of the current dose basis of 4 millirem a year.

nonbinding Superfund guidance. Also in 1997, NRC finalized its own cleanup standards—decommissioning standards for its licensees—reflecting 25-millirem-a-year all-pathway protection. [26] In correspondence with NRC, EPA has objected to NRC's standard as potentially not protective in all cases. [27] In some cases, both EPA's and NRC's approaches have both been applied to the same site, raising questions about potential dual regulation.

EPA and NRC have long disagreed on standards for cleaning up and decommissioning the nation's nuclear sites. As far back as 1992, the two agencies signed a memorandum of understanding, agreeing to avoid unnecessary duplication of regulatory requirements. In 1994, we reported that EPA and NRC were involved in potentially costly dual regulation of NRC's licensees. Our previous report's recommendation that the agencies pursue consensus on acceptable risk was a factor in the establishment in 1995 of the Interagency Steering Committee on Radiation Standards, which is cochaired by EPA and NRC. However, despite numerous staff initiatives and some progress in cooperation, this committee has not resolved major issues between the two agencies. The two agencies have continued to use separate approaches in setting standards for cleaning up and decommissioning nuclear sites, especially when groundwater protection is involved. Consequently, perceived dual regulation by EPA and NRC continues to complicate the cleanup and decommissioning process at some sites where both agencies' standards may apply, potentially causing duplication of effort and regulatory delays, adding to facilities' compliance costs, and raising public questions about what cleanup levels are appropriate and safe. [28]

[26] In addition, DOE has issued public protection orders for its nuclear installations that generally conform to NRC's approach, including all-pathway protection without extra groundwater protection, as well as dose reductions to levels as low as reasonably achievable. DOE has proposed to convert its order into a regulatory standard, but EPA has opposed the draft standard as inconsistent with Superfund requirements.

[27] In 1994, NRC considered standards comparable to EPA's—15 millirem a year, with separate groundwater protection to drinking water standards—but changed to an all-pathway, 25-millirem-a-year approach after further analysis and public comments on the proposed rule.

[28] Also, over the years, differences between EPA and DOE concerning standards and acceptable risks for cleanups at DOE sites have contributed to regulatory delays and higher regulatory and cleanup costs while raising public questions about what cleanup levels are appropriate. See Nuclear Cleanup: Completion of Standards and Effectiveness of Land-Use Planning Are Uncertain (GAO/RCED-94-144, Aug. 26, 1994).

For example, in individual situations at NRC-licensed sites, EPA has indicated that it might not view cleanups performed to NRC's standards as adequately protective under its Superfund guidance. EPA considers such potentially conflicting situations to be exceptions, not the rule. EPA raised the matter of the standards' adequacy twice in 1999 in connection with nuclear power plants in Maine and Connecticut where the decommissioning process is under way, and again in connection with the West Valley, New York, nuclear site, a DOE-operated facility where NRC has a legislatively mandated regulatory role. In such situations, the licensee may construe EPA's involvement as a warning that EPA could reevaluate the adequacy of a cleanup that has met NRC's requirements. In the New England cases, the licensee has thus far responded to the prospect of dual regulation by proceeding with its decommissioning plans, assuming that it will be able to comply with both agencies' standards. [29] In the West Valley case, it remains to be seen whether NRC's or EPA's approach will finally be chosen for the site.

Our 1994 report found that U.S. radiation standards reflected a lack of federal agency consensus on acceptable radiation risk to the public, particularly between EPA and NRC. We recommended that the two agencies take the lead in pursuing interagency consensus on acceptable radiation risks to the public. In succeeding years, EPA and NRC have attempted to resolve their conflict over cleanup standards by means of a memorandum of understanding that would clarify their potentially conflicting, dual regulation of NRC-licensed sites. In August 1999, the House Appropriations Committee strongly encouraged the two agencies to develop such a memorandum and directed them to report to the Congress by May 1, 2000, on the status of their efforts to do so.

In early May 2000, EPA and NRC informed the Committee by separate letters that they are developing such a memorandum, although a jointly drafted version of the memorandum does not yet exist. To date, EPA officials see such a memorandum as providing an outline of consultation procedures for EPA and NRC to use during NRC's decommissioning process when NRC requests EPA's assistance. It is unclear whether the memorandum will consider whether EPA should retain its authority to conduct a Superfund evaluation of an NRC-licensed or -decommissioned

[29]The licensee has stated that it can meet more stringent standards of 10 millirem a year, plus extra groundwater protection to the equivalent of 4 millirem a year, as imposed by the state of Maine.

facility when a stakeholder requests such an evaluation. EPA believes it should retain this authority and has provided guidance to its regional offices on how to proceed when a stakeholder asks for an evaluation. According to this guidance, EPA believes that at the vast majority of NRC-licensed sites, cleanups that meet NRC's standards will also meet Superfund standards. An NRC draft version of the memorandum assumes that EPA will defer to NRC's radiological cleanup and decommissioning standards and regulations and will exempt most NRC-regulated sites from the application of the Safe Drinking Water Act and Superfund. NRC's version reflects the Commission's view that clearly delineated jurisdictions for the two agencies are needed.

Costs Vary to Comply With Different Radiation Standards

Long-term costs related to complying with current and prospective U.S. radiation standards have generally not been comprehensively estimated, but these costs will be immense, likely in the hundreds of billions of dollars.[30] The potential size of these costs is reflected in DOE's long-term funding estimates for high-level waste disposal and nuclear cleanup projects. These estimates total more than $200 billion over many decades and could increase, according to DOE. In addition, DOE's, NRC's, and EPA's analyses of individual nuclear sites' cleanup options show that site-specific compliance costs can vary significantly depending on the restrictiveness of the standards. As might be expected, the analyses show that compliance with more restrictive standards—for example, exposure limits of a few millirem a year—costs considerably more than compliance with less restrictive standards—for example, limits of 100 millirem a year. Site-specific DOE analyses estimate multimillion-dollar cost differences between less restrictive and more restrictive protection levels, in some cases. These analyses further show faster rising costs to achieve the most restrictive protection levels.

[30]Annual costs and benefits of environmental regulations have been estimated to total many billions of dollars annually. For example, see R. Hahn, and J. Hird, "The Costs and Benefits of Regulations," Yale Journal on Regulation, vol. 8 (1991), pp. 233-78.

Costs of Implementing High-Level Waste Standards

To comply with high-level waste standards, DOE has projected multibillion dollar costs, whether or not the Yucca Mountain repository is developed. Radiation protection standards for Yucca Mountain have not been finalized,[31] but DOE has estimated funding of over $43 billion (in 1998 dollars) for the total repository system to 2116, in large part to help ensure that the public is protected from exposure to the waste stored there. According to DOE's latest estimates, long-term funding for the repository could go over $55 billion. Alternatively, if the repository is not built, DOE has estimated expenditures of about $52 billion to $57 billion to store high-level waste for 100 years at existing sites around the country. From the enactment of the Nuclear Waste Policy Act of 1982 through fiscal year 1998, DOE spent about $7 billion (in 1998 dollars) for its repository program. [32]

EPA, NRC, and DOE have not estimated the total difference in compliance costs under the conflicting standards proposed by EPA and NRC for Yucca Mountain. DOE officials said that most of the projected increases in the repository's costs can be associated with design changes resulting from the combination of EPA's proposed groundwater standards, the need to provide the level of confidence in the repository's performance required for a rigorous NRC licensing process,[33] and the influence of external oversight advisory bodies and peer review panels. DOE estimated that cost increases have totaled over $10 billion since 1993 to achieve added confidence that restrictive performance and radiation protection requirements can be met over thousands of years. For example, in 1993 a repository-performance-related increase of $7 billion (in 1999 dollars) came from a design change involving the use of more robust, cylindrical waste containers. Furthermore, DOE is considering an additional cost of $3.7 billion (in 1999 dollars) for water-diverting titanium drip shields (over the waste

[31]DOE officials said that since the 1990s, they have been designing the repository to more than meet prospective radiation standards that EPA and NRC might issue.

[32] At another nuclear waste disposal facility that is already in operation, the Waste Isolation Pilot Project, where EPA's transuranic waste disposal standards are operative, DOE projects funding to 2070 at $7.7 billion. In addition, state compacts and unaffiliated states have to date incurred almost $600 million in costs for planning and developing potential low-level waste disposal sites, although no sites have been built. See *Low Level Radioactive Wastes: States Are Not Developing Disposal Facilities* (GAO/RCED-99-238, Sept. 17, 1999).

[33]According to DOE and EPA, NRC's proposed "reasonable assurance" performance objective for the repository may be more stringent and costly to implement than the "reasonable expectation" compliance objective in EPA's proposed standards. NRC disagreed that this would necessarily be the case.

containers) intended to protect the repository from potential water incursion, as well as to meet EPA's proposed groundwater protection requirements in a rigorous NRC licensing process. Further design enhancements to achieve a cooler repository, which would keep temperatures in the repository below the boiling point of water, as favored by the Nuclear Waste Technical Review Board, could add about $2 billion more to costs. According to DOE and NRC officials, the latest design is essentially an attempt to achieve a virtually "no radioactive release" facility at Yucca Mountain. These officials maintain that such a design may not be needed to implement less restrictive standards such as 15-, 25- , or 100-millirem-a-year all-pathway exposure limits.

Costs of Implementing Nuclear Cleanup and Decommissioning Standards

Although comprehensive data on the costs of complying with nuclear site cleanup and decommissioning standards were unavailable, these costs could be immense in the long term. For example, complying with EPA Superfund cleanup and other environmental requirements may cost DOE several billion dollars annually, judging from the fact that the agency's fiscal year 1999 appropriation for the overall environmental management and cleanup of its nuclear facilities was about $5.8 billion. The agency's compliance activities could cost hundreds of billions of dollars and could extend for decades into the future, according to long-term funding estimates for environmental cleanup projects. The agency has projected funding for environmental cleanup at its nuclear sites from fiscal year 2000 through fiscal year 2070 to be anywhere from about $151 billion to $195 billion (in 1999 dollars). DOE spent about $52 billion for cleanup from fiscal year 1989 through fiscal year 1999. The overall bill for DOE's nuclear cleanup is uncertain and could go higher. According to DOE, the future costs of many of its cleanup programs are difficult to quantify because many projects are still in the planning stage. Moreover, as we noted in 1999, the data on some sites may not be reliable, in part because many field sites based their cost estimates on assumed cleanup levels that have not been finalized.[34] In addition, the operators of NRC-licensed nuclear facilities, including over 100 power plants, may spend over $38 billion for

[34]See *Nuclear Waste: DOE's Accelerated Cleanup Strategy Has Benefits but Faces Uncertainties* (GAO/RCED-99-129, Apr. 30, 1999). According to DOE, about 85-90 percent of its environmental management budget is directed toward ensuring compliance with the large number of legally enforceable cleanup and compliance agreements in place at major sites around the country. Such compliance involves not only EPA requirements, such as Superfund, but also any applicable state requirements, as well as DOE's own radiation protection orders.

decommissioning in coming decades, according to the Nuclear Energy Institute.

Even though EPA, NRC, and DOE generally did not have estimates for all U.S. nuclear sites of the costs of complying with different cleanup standards to achieve different protection levels,[35] officials from these agencies said that achieving more restrictive protection levels, especially the most restrictive levels—in the range below 100 millirem a year—can be considerably more expensive. To support their statements, they cited various generic and site-specific cost analyses conducted by DOE, NRC, and EPA. Our examination of these cost analyses generally confirmed higher estimated costs to comply with more restrictive cleanup levels for contaminated soil, as might be expected. Conversely, cost estimates were considerably less to comply with less restrictive soil cleanup levels. For example, analyses comparing the costs of achieving EPA's and NRC's conflicting all-pathway cleanup levels—15 millirem a year and 25 millirem a year, respectively—show cost differences in the millions of dollars for some sites—and even greater cost differences to achieve cleanup levels below 10 millirem a year. Analyses also show potential multimillion-dollar cost differences between the 15 to 25 millirem-a-year range and the less restrictive 100-millirem-a-year level.

Among the analyses we examined were a generic analysis by NRC to support its decommissioning standards and numerous site-specific cost analyses done by DOE in the course of analyzing cleanup options for its nuclear weapons complex. The estimated costs of meeting different soil cleanup levels for selected sites are summarized in table 1 and discussed in more detail in appendix V.

[35] An exception is a preliminary regulatory analysis done by EPA in 1996 to support its proposed cleanup standards. The analysis showed incremental cost differences in the low billions of dollars to meet various cleanup levels below 100 millirem a year. See app V.

Table 1: Estimated Costs to Achieve Different Soil Cleanup Levels at Selected DOE Sites and Generic NRC-Licensed Sites

Dollars in millions

Agency/site/ analysis date	Cost of 100 millirem a year	Cost of 25 millirem a year	Cost of 15 millirem a year	Cost of less than 10 millirem a year
DOE/Nevada Test Site and test ranges/1995	35	131	240	1,003[a]
DOE/Brookhaven Laboratory waste facility/1998	15.9	24.4	28.2	64.5[b]
NRC-licensed power plant[c] /1997	0.17	0.31	0.41	1.44[d]
NRC-licensed metal extraction facility[c]/1997	5.30	6.21	7.33	13.86[d]

Note: Totals do not represent overall estimates of cleanup costs, which may include costs for activities other than soil cleanup, including the decontamination and removal of equipment and structures, as well as liquid waste treatment.

[a]5 millirem a year.

[b]1 millirem a year. Totals are present values.

[c]Generic site.

[d]3 millirem a year.

Source: GAO's presentation of data from DOE and NRC.

As shown in table 1, for the listed sites, the estimated costs to achieve different soil cleanup levels vary, from hundreds of thousands of dollars in some cases to hundreds of million dollars in other cases. The cleanup costs also accelerate faster to achieve the most restrictive levels. For example, for the Nevada Test Site, from a 100-millirem-a-year baseline, the costs increase over three times and over six times to achieve the 25-millirem-a-year and 15-millirem-a-year levels, respectively, but over 28 times to achieve the 5-millirem-a-year level. Similarly, for the Brookhaven facility, from a 100-millirem-a-year baseline, the costs increase about 53 percent to achieve the 25-millirem-a-year level, about 77 percent to achieve the 15-millirem-a-year level, but over 300 percent to achieve the 1-millirem-a-year level. DOE and NRC officials said the large cost variations for different sites reflected site-specific factors, including the ratio of soil and building contamination, exposure and land-use scenarios, and waste disposal options. Officials said cost factors include not only the degree of on-site remediation, but also soil sampling and analysis to demonstrate compliance with standards, as well as procedural and other costs.[36]

Fewer analyses of the costs of complying with EPA's extra groundwater protection approach for nuclear cleanups were available. However, DOE's groundwater remediation analyses for aquifers at the Idaho National Engineering and Environmental Laboratory and at the Brookhaven National Laboratory showed that the additional costs of achieving drinking water standards at these sites could approach several hundred million dollars and a few million dollars, respectively, depending on the remediation option chosen. (See app. V.)

Conclusions

Although conclusive scientific evidence of the effects of low-level radiation is lacking and may not soon be found, U.S. regulators still have the challenge of developing radiation standards that represent their best estimates of acceptable radiation risks to the public. In this regard, as a national decision on high-level-waste disposal at Yucca Mountain approaches, and as EPA and NRC both continue to administer the cleanup and decommissioning of nuclear sites, it is important that the two agencies agree on protection approaches and policies for these regulatory applications. However, it does not appear that EPA and NRC will readily agree on appropriate groundwater protection approaches for Yucca Mountain. Also, EPA and NRC have been working on a memorandum of understanding since before August 1999, when the House Appropriations Committee encouraged them to clarify their conflicting regulatory roles related to nuclear facility cleanup and decommissioning, with little progress. Looking back, we note that they have not successfully addressed this matter since at least 1994, when we recommended that they pursue consensus on acceptable radiation risks to the public. Given the agencies' historical differences and lack of recent progress, without congressional intervention, they may not resolve their differences.

It is of note that EPA and NRC, while disagreeing over appropriate public protection levels, are both regulating at levels where the harm of radiation and the health benefits of radiation standards may not be clearly

[36]These analyses do not consider overall site cleanup costs, which may include many factors, such as the costs of decontaminating and removing structures and treating liquid waste. The analyses often estimated hypothetical cancer deaths averted from meeting various protection levels.

demonstrable. Regulating at these levels, well below the range where radiation effects have been conclusively verified, is essentially a policy judgment. Such an approach may arguably be prudent, in accordance with regulatory use of the linear model, which both agencies endorse. However, it will also be expensive, because compliance costs accelerate to achieve the lowest exposure levels, as our work confirms. The potential acceptable risks, health benefits, and costs of EPA's and NRC's differing regulatory approaches will be of interest to the Congress as it continues to focus on nuclear health and safety issues of national importance, such as the proposed Yucca Mountain repository and the cleanup and decommissioning of federal and commercial nuclear sites. These risks, benefits, and costs will also affect the public's belief in and acceptance of any resolution of their conflicting viewpoints that the two agencies may achieve.

Matters for Congressional Consideration

The congressional committees of jurisdiction may wish to reconcile EPA's and NRC's policy differences on groundwater protection for Yucca Mountain. Also, in connection with the two agencies' efforts to complete a memorandum of understanding relating to the cleanup and decommissioning of nuclear sites, these Committees may wish to clarify the agencies' regulatory responsibilities.

Agency Comments

We provided NRC, DOE, and EPA with a draft of this report for their review and comment. NRC found the report to be fundamentally sound and said it should help the Congress understand the long-standing differences between EPA and NRC. NRC supported our conclusions that federal agencies should agree on decommissioning and high-level waste policies and approaches to ensure consistent standards and public protection. DOE found the report to be factual and balanced. EPA disagreed with the report, in separate letters from its Office of Radiation and Indoor Air and Office of Emergency and Remedial Response. The Director, Office of Radiation and Indoor Air, said EPA interprets the information presented in our report differently, and as a result, EPA disagrees with the report's conclusions. The Director, Office of Emergency and Remedial Response, said, among other comments, that the report inaccurately portrays EPA and NRC as making little progress in their negotiations on a memorandum of understanding to clarify the two agencies' regulatory roles and responsibilities related to the cleanup and decommissioning of nuclear facilities. EPA mentioned recent and continuing efforts by the two agencies to better clarify their respective regulatory roles through such a memorandum. While recognizing these recent initiatives, we note that since as long ago as 1992, the two agencies have been unsuccessful in addressing this matter, and on this basis we still question whether the two agencies' most recent initiatives will resolve their differences without congressional intervention.

NRC, DOE, and EPA provided technical clarifications to the draft report, which we incorporated into the final report where appropriate. EPA's, NRC's, and DOE's comments and our evaluation of them are included in appendixes VI, VII, and VIII.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 20 days after the date of this letter. At that time, we will send copies to the Honorable Carol Browner, Administrator, Environmental Protection Agency; the Honorable Richard Meserve, Chairman, Nuclear Regulatory Commission; and the Honorable Bill Richardson, Secretary of Energy. We will also make copies available to others upon request.

If you have any questions about this report, please contact me or (Ms.) Gary L. Jones on (202) 512-3841. Key contributors to this assignment were Duane G. Fitzgerald and Dave Brack.

Sincerely yours,

Jim Wells

Jim Wells, Director, Energy, Resources, and Science Issues