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Benefit-Cost-Risk Analysis of Alternatives for Greater-Confinement Disposal of Radioactive Waste, T.L. Gilbert, C. Luner, J.M. Peterson (ANL).

The Low-Level Waste Management Program, established by the U.S. Department of Energy in 1978, has been actively engaged in planning, research, and development for safe and cost-effective methods for disposal of low-level waste. The need for a program that addressed the hazards of waste intermediate between typical low-level waste (LLW) and high-level waste (HLW) became apparent in the early stages of the program. Waste of this kind is classified as LLW for regulatory purposes but contains radionuclides at concentrations that exceed current regulatory limits for disposal in a commercial LLW disposal facility. Demonstration programs for resolving technical problems associated with the greater-confinement disposal (GCD) needed for such waste have been in progress for several years at the Nevada Test Site (with technical support from Los Alamos National Laboratory) and the Savannah River Laboratory. This work has progressed to the point where a more quantitative assessment of the cost-effectiveness of different GCD methods is needed in order to provide a sharper focus for further work. The work described in this summary was undertaken in response to that need.

Seven alternatives are included in the analysis: (1) near-surface disposal; (2) improved waste form; (3) below-ground engineered structure; (4) augered shaft; (5) shale fracturing; (6) shallow geologic repository; and (7) HLW repository. These alternatives are representative generic facilities that span the range from LLW disposal practice to HLW disposal practice, tentatively ordered according to an expected increasing cost and/or effectiveness of confinement. They have been chosen to enable an assessment of the degree of confinement that represents an appropriate balance between public health and safety requirements and costs rather than identification of a specific preferred facility design.

The objective of the analysis is to provide a comparative ranking of the alternatives on the basis of benefit-cost-risk considerations. Because the benefits have already accrued in the actions that generated the waste and because no use of the waste that would lead to further benefits is considered in the analysis, the benefits for all alternatives are equal and do not, therefore, affect tne ranking. Thus, the benefit-cost-risk analysis reduces to a problem of evaluating--for each alternative and a unit quantity of GCD waste--a ranking parameter, $R = C + H$, where C is the cost in dollars and H is the health risk converted to dollars. The ranking parameter provides a means for scaling as well as ranking the different alternatives, i.e., for determining whether the difference in cost-effectiveness for two alternatives is small or large. The value of the ranking parameter is normalized to unity for a near-surface facility designed to satisfy the new 10 CFR 61 criteria for LLW (but with a ranking parameter evaluated for the GCD waste stream). Costs and risks that are common to all alternatives do not affect the ranking and have only a small effect on the scaling. The ranking and scaling are also insensitive to factors that are common to all alternatives (e.g., dispersal of radionuclides that reach a given release point, or demographic parameters). The comparative analysis is, therefore, less sensitive to errors and uncertainties than a standard benefit-cost-risk analysis that uses the absolute net present value (the sum of the discounted and dollar-converted benefits, costs, and risks).

The cost estimates are based on the assumption that the greater-confinement facility (GCF) is co-located at a site used for near-surface disposal of ordinary LLW. Many of the site preparation and service facilities are, therefore, common to all alternatives and cancel out in the comparative analysis. It is assumed that a certain area of the LLW site is reserved for the GCF. The added cost of selecting a site that is suitable for GCD trenches, structures, or augered shafts is assumed to be common to all GCD alternatives except a shallow geologic repository, which is considered separately. (It is assumed that use of a HLW repository would involve co-disposal with HLW.) The cost estimates include incremental costs associated with facility construction, operations, closure, and maintenance during the period of active institutional control.

The health-risk estimates are based on dose estimates using the relation $H = cD$, where D is the sum of the occupational dose, intruder dose, and population dose, and c is a dose-to-dollars conversion factor. A value of $c = \$1000/\text{rem}$ is used for the analysis. A factor $\exp(-at)$, with $a = 0.0002/\text{yr}$, is used for weighting future risks. This factor is introduced on the basis that estimation of risk beyond about 10,000 years is too uncertain to permit a credible analysis.

The dose estimates are based on a pathways analysis in which the individual dose is analyzed into a sum of products of conversion factors of the form:

$$D(t) = \sum_{\substack{\text{pathways} \\ \text{radionuclides}}} (D/E) \times (E/C) \times (C/R) \times (R/S) \times S \qquad (1)$$

where D(t) is the individual dose rate as a function of time, D is the dose-equivalent rate to the whole body or critical organ; E is the exposure rate (external radiation intensity or quantity of internal emitters inhaled or ingested annually), C is the concentration of radionuclides in the food, water, air, or ground at the point of exposure; R is the rate of release of radionuclides or radiation from the waste into the near-vicinity environment; and S is the source term, which is here taken to be the concentration of a radionuclide in the waste. Each conversion factor (D/E, E/C, etc.) corresponds to an input/output or cause/effect relationship for a particular block in a block-and-line pathway diagram (i.e., to a particular subsystem of the entire system), and is a function of all the parameters that characterize the subsystem to which the block corresponds. The conversion factors are taken from the NRC pathway analysis for 10 CFR 61, with modifications as needed to represent features of GCD alternatives not covered by the NRC analysis.[1] Separate analyses, with different conversion factors, are needed for workers, intruders, and individuals residing within the affected region.

The individual doses from Equation 1 for workers, inadvertent intruders, and the general population are summed over the appropriate populations in order to obtain the total population dose, $D_p(t)$. A penalty function for individual dose rates that exceed regulatory limits is used in summing in order to eliminate alternatives (or waste streams) that would not be in compliance with radiation protection standards and regulations. The time-dependent total dose is then integrated with the discount factor

$$D = \int_0^{\infty} D_p(t)\exp(-at)dt \qquad (2)$$

in order to obtain the total discounted dose for use in calculating the ranking parameter $R = C + cD$.

A ranking of GCD alternatives based on the above-described procedure will be presented.

1. U.S. Nuclear Regulatory Commission. 1981. Draft Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste". NUREG-0782. Volumes 1-4.