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THE PERSPECTIVE OF WASTE ISOLATION RESEARCH ISSUES AND ASSESSMENT
OF CONSEQUENCES FOR RADIONUCLIDE RELEASE*

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INTRODUCTION

Nuclear waste management has recently experienced a proliferation of technical and social issues which have seemingly confounded the stabilization and implementation of effective policy. Advocates and critics alike have shown an inexhaustible capacity to arouse public and scientific interest in these matters. This paper is restricted to the examination of some current technical issues in the perspective of their role in determining consequences of radionuclide release to the biosphere. The consequence assessments done for the Waste Isolation Pilot Plant (WIPP) site are used as a reference and compared with some current data on various technical issues. The comparisons and conclusions drawn apply specifically to WIPP configurations at the WIPP site. In addition, these initial assessments provide the basis for a method to identify key issues and eliminate inconsequential ones, thereby allowing commensurate allocation of research and development resources.

Determination of the potential hazard from disposal of nuclear waste is addressed by considering various scenarios in which the primary isolation mechanism--the media immediately surrounding the repository--is assumed to be breached. A series of these scenarios have been identified for WIPP.¹ Consequences of the radionuclide release in the scenarios have been determined and published in the WIPP Draft Environmental Impact Statement.² This document presents the results of five different scenarios.

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1. An open borehole which penetrated the repository allowing fluid transmission between lower and upper aquifers.
2. Two interconnected penetrations of overlying formations that allow fluids to enter the repository at one location and escape into the upper aquifer at another.
3. Diffusion of radionuclides from a flooded repository into overlying aquifers.
4. A bounding case in which the total flow in the overlying aquifer is assumed to enter the repository, mobilize radionuclides, and reenter the overlying formations.
5. A direct access scenario in which a drilling operation intercepts a high concentration of radionuclides, thereby exposing the drill crew.

The scenario chosen for comparison is depicted below in Figure 1.

FIGURE 1

If this scenario is a 9-inch uncased borehole allows up to 600 ft/day, unconsolidated brine (230,000 ppm) to enter the repository floor below, dissolve the salt in the repository, and enter the overlying aquifer at 410,000 ppm. The assumptions within this scenario will be compared with the related issues of waste form stability, brine migration, radionuclide migration, and borehole plugging.

A solid waste form that chemically or mechanically binds radio-nuclides has been proposed as one of the "multiple barriers" in a repository. While stable waste forms, under appropriately specified conditions, can no doubt serve that function, the degree of reliance on that barrier has not yet been assessed. In the WIPP consequence assessments, the existing defense transuranic (TRU) wastes were not of sufficient uniformity to specify any resistance to entrainment or solution by breaching fluids; consequently, the waste was assumed to go into solution at the same rate as the salt. For scenario 1, the assumptions of constant flow rate imposed by overlying aquifers and constant salt injection rates result in a gradual increase in effective borehole diameter and a commensurate reduction in surface dissolution rate as the surface area increased. The effective dissolution rate and borehole radius from these simple assumptions are shown in Figure 2.

FIGURE 2

Also shown in Figure 2 are some representative data on glass from Westsik and Turcotte³ at various temperatures. Admittedly, leach rate under controlled laboratory conditions may not be the most appropriate indicator of transport of ions from solids into solution. The effects of conditions imposed by waste degradation and interaction with the host rock, which include eh, ph, extent of devitrification, and radionuclide speciation must be considered. However, any emphasis on detailed interaction chemistry must be done only after appropriate consideration of the importance of specific parameters in providing overall radionuclide isolation.

In the WIPP case, the scenario analyzed gave very small predicted doses (less than 0.10 millirem per year for a maximally exposed individual in scenario 1), yet the stability of the waste form played no role. Moreover, the assumed dissolution rates were several orders of magnitude higher than could be anticipated with waste forms such as glass.

An analogous problem is the role of protective canisters surrounding the waste form. WIPP scenarios to date have not relied on any protection from canisters. Nevertheless, recent experimental tests on various alloys⁴ have identified several candidates which exhibit corrosion lifetimes of several hundred years. Some tests were performed under conditions which simulated brine inundation and varying degrees of oxidation potential including the effects of radiolysis. While it is unlikely that an objective assessment of consequences from a repository would rely entirely on an impervious canister, the technology for enhanced waste canisters under repository conditions can be developed and relied upon for increased confidence in the isolation system. Canister material development and selection can, however, play an important role in future repository applications by assuring compliance with institutional constraints such as retrievability.

BRINE MIGRATION

Brine flow in salt have been the subject of intense controversy over the potential migration and accumulation of brine around non-producing wastes. At present, the mechanisms which determine the initiation or propagation of fluid motion are being studied experimentally⁵ but have not yet been sufficiently investigated to provide minute resolution of rates or amounts of influx. The salient aspect of brine migration is that for long-term isolation it plays an insignificant role in releasing radionuclides when compared with the fluids which are assumed to intrude in consequence assessment scenarios. Most assessments using analytical models for brine influx to HLW canisters have predicted integrated flows less than 10-50 liters. The scenarios for WIPP assumed that up to 6×10^6 liters/year of fluids were allowed to enter the repository via a natural or man-made breach of the salt.

Recent experiments with a 1.5 kW heater in a 1-meter salt block⁶ at Sandia Laboratories used higher temperatures and gradients than anticipated for HLW canisters. Fluid migration rates of approximately 1 gm/day (decreasing to 1/2 gm/day at the end of testing) were observed over a period of 100 days. More significant, however, is that these tests revealed the possibility of mechanisms such as vapor phase transport through the salt. These correlations indicate that moisture collected during the experiment may be induced by the maintenance of very low vapor pressure near the collecting surfaces and that fluid release is greatly enhanced by changing the stress field surrounding the heated source, especially upon power shutdown. Both of these conditions, which promote experimental observation of moisture collection, will not occur with actual waste canisters.

The most significant impact of brine migration would be the potential complication of retrieval operations. However, this impact has been considered by studies on waste form degradation or canister corrosion that have assumed brine is present. The results of such investigation indicate that both materials and waste forms have sufficient durability to easily endure the retrieval period under worst-case conditions. If further confidence is needed, engineering barriers or reduction of power densities can be used to eliminate concern about brine migration.

RADIONUCLIDE MIGRATION

Consequence assessments for WIPP have assumed that the fluids which violate the repository and entrain radionuclides are introduced into overlying aquifers. This hydrologic flow pattern is characterized by descriptions of aquifer properties and by the sorptive capacity of the rocks. Laboratory studies of distribution coefficients⁷ (K_d) have been used to establish reference values for the Rustler aquifer which overlies the WIPP site.

The sensitivity of the consequences to the values assumed has recently been addressed by Fertney.⁸ This study investigated the concern over potential reduction in sorption by complex formation or radiolytic induction of redox reactions. The results serve to place in perspective the importance of precise resolution of sorptive properties.

In this analysis, the sorptive properties of the Rustler aquifer were systematically reduced, and the effect on consequences predicted by scenarios for a TRU repository was examined. Cases considered were:

	Element	K_d (ml/g)	Element	K_d (ml/g)
DEIS Values	Sp	700	I	0
	U	1	Tc	0
	Th	2200	Pb	25
	Pu	2100	Sr	0
	Cs	15		
Case 3	Pu*	10		
Case 2	Pu*	1		
Case 1	Pu*	0		
Case 0	All	0		

*All others at DEIS values

The results indicated in Figure 3 reveal the impact on individual 50-year dose commitments and emphasize the sensitivity to changes in plutonium retardation. Maximum whole body doses in Case 0 in which all radionuclides moved at the same velocity as the plutonium did not exceed 3 mrem/yr. A K_d of 10 for Pu (case 3) was sufficient to reduce the dose to 0.002 mrem/yr, essentially the

FIGURE 3 - WHOLE BODY DOSE, SCENARIO 1

same level as with a value of 2100. Hence, while a reduction of K_d to 0 and 1 result in a thousandfold increase in dose, the dose was still inconsequential, and reasonably small K_d 's are sufficient to dramatically reduce predicted doses.

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Sensitivity studies of this type are just beginning, but these initial studies point out that certain ranges of parameters are not important to overall system consequences.

BOREHOLE PLUGGING

A long-standing issue in waste management is the requirement of sealing boreholes and shafts. Experimental programs⁹ have been initiated to investigate the feasibility of emplacing and monitoring performance of plugs. These programs, when coupled with supporting programs to assess long-term stability of plugging materials, will provide the basis for sealing repositories upon decommissioning. While adequate plugs appear technically feasible, it should be stated that in all consequence assessments performed for WIPP, totally unsealed penetrations were assumed. Hence, the existence of a competent seal was not required to limit consequences to a small fraction of natural background. Borehole plugs can therefore be relied upon as an additional measure of protection, yielding further confidence beyond that provided by bounding case studies. They should not be viewed as essential components in assuring isolation.

SUMMARY

The limitations of research resources to address technical issues for nuclear waste management requires a realistic assessment of their importance. The most appropriate method for making this assessment is the combination of system studies, which include consideration of the role of all protective barriers, and consequence assessment models that can estimate the potential hazard imposed upon man for assumed violations of these barriers. Sensitivity analyses on certain issues can then be performed to determine the impact of various descriptive parameters.

Work commensurate with this strategy has been initiated at Sandia. Some conclusions drawn from these studies specifically applicable to WIPP for the scenario considered are that:

- a. Waste form and protective containers are not essential as barriers. Assumed radionuclide dissolution is far in excess of that possible with developmental waste forms.
- b. Breem migration plays no significant role in long-term isolation; emplacements to retrievability can be avoided with numerous technical alternatives.

- o Radionuclide sorption in geomedia near repositories plays an important role in reducing consequences, but sites with favorable geologic and hydrologic settings such as WIPP can tolerate essentially no reliance on sorption and still achieve inconsequential predicted doses. Plutonium sorption with K_d greater than 10 are sufficient to eliminate direct doses from plutonium.
- o Borehole plugs are not required for primary protection.

Continued scientific resolution of both real and perceived issues can, however, provide additional assurance and public confidence that consequences can be reduced beyond those predicted in bounding scenarios. In addition, such investigation will assure that appropriate limits are instituted for defining parameters and that all assumptions in predictive models are technically sound. Nevertheless, all who participate in a socially significant technical problem such as nuclear waste management should endeavor to clearly distinguish between critical issues and those which merely require additional refinements.

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