ALTERNATIVE WASTE DISPOSAL CONCEPTS
AN INTERIM ASSESSMENT

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INTRODUCTION

For many years, research and development have been conducted by government and industry throughout the world to demonstrate acceptable methods for the management and permanent disposal of radioactive wastes produced by commercial nuclear power plants. In the United States, the Department of Energy (DOE), its predecessor organizations, and various contractors have studied and developed many disposal concepts in order to ensure that safe isolation can be provided at acceptable costs to society. Disposal concepts which have been assessed and compared include: mined geologic, subseabed, space, partitioning and transmutation, chemical resynthesis, very deep hole, rock melting, island, ice sheet, and reverse well.[1-3] In its report to the President, the Interagency Review Group (IRG) on Nuclear Waste Management identified several of these for further consideration.[4]

During the latter part of 1979, Bechtel conducted an Alternative Waste Disposal Concepts Study (AWDCS) for Battelle's Office of Nuclear Waste Isolation (ONWI)[a], which represented a continuing effort in the definition and assessment of some of the more promising waste disposal concepts. In the study, preliminary definitions of waste disposal systems were developed and a preliminary assessment was made of several alternatives to mined geologic isolation. The detailed results of the study are contained in an ONWI report[5] soon to be published.

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[a] Under Battelle-ONWI subcontract E512-00100

STUDY DEFINITION AND BASES

The AWDCS was fundamentally a systems study to compare the merits of several alternative waste disposal concepts against a number of assessment criteria and attributes. While it was not a design study, a substantial amount of the total effort was spent in defining complete waste management systems for each of the study cases. Eight alternative waste management cases, shown in Table I, were defined and assessed. They were developed from appropriate combinations of two fuel processing and five waste disposal concepts. The fuel processing concepts are:

(1) Encapsulation of intact spent uranium oxide fuel assemblies in steel canisters to prepare them for final disposal as part of a once-through fuel cycle.

(2) Reprocessing of spent mixed-oxide fuel (with the accompanying recycling of uranium and plutonium) and encapsulation of HLW and other reprocessing waste in preparation for final disposal.

The waste disposal schemes used in case development are:

(1) Mined geologic Repository: At a depth of 600 meters.

(2) Very deep hole: 10,000 meters deep, with canisters stacked in the lower 1500 meters.

(3) Rock melting: Placement of high heat producing waste in a deep rock cavity and allowing the heat to melt the rock, forming a dispersion resistant waste/rock matrix when the resultant waste and rock solidify.

(4) Subseabed: Canisters are emplaced in very stable sediments of the abyssal hills of either the Atlantic or the Pacific.

(5) Space: The waste is placed in solar orbit.

While there are 10 possible study cases obtainable by simply combining the two processing concepts with the five disposal schemes, two combinations were eliminated because the spent fuel waste form was considered inappropriate for the rock melting and space disposal concepts.

The case definitions were developed in such a way as to provide a consistent basis for waste disposal assessment. Each study case was defined to include the processing, encapsulation, storage, transportation, and disposal of all waste streams generated in the back end of the fuel cycle, as well as the transportation of uranium and plutonium to recycle facilities for those cases involving reprocessing. A 5,000 MTHM per year system operating at equilibrium at some future time is assumed for all cases.

TABLE I. Study Case Identification

	Processing Concepts	
Disposal Concepts	Spent Fuel Encapsulation	Reprocessing and Recycle
Mined Geologic Repository	Case A	Case D
Very Deep Hole	Case B	Case E
Rock Melting	--	Case F
Subseabed	Case C	Case G
Space	--	Case H

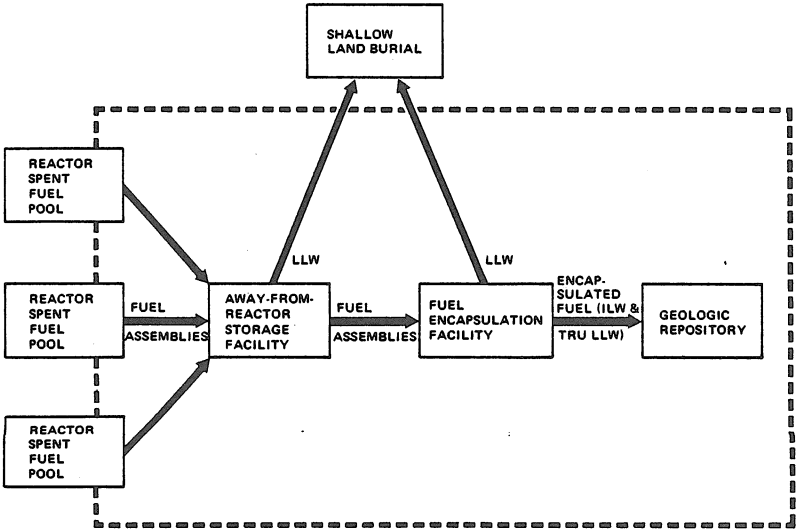
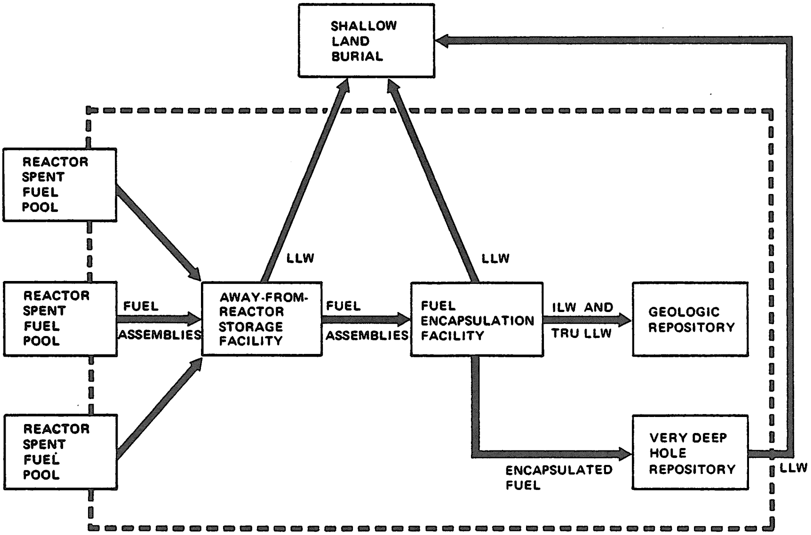


Fig. 1. Fuel Cycle Diagram - Case A
Spent Fuel in a Mined Geologic Repository

The scope of the basic spent fuel disposal case is shown in Fig. 1. Case A involves the simple encapsulation of spent fuel and its emplacement, with small amounts of intermediate and low level TRU waste, in a mined geologic repository. The facilities and transportation steps within the dotted line are those included in the study. Fuel assemblies are transported at age one year from the reactor spent fuel pools (which are outside the study) to interim AFR storage, where they are held until they are 10 years old. From the AFRs the assemblies are transported to a fuel encapsulation facility. After encapsulation, they move to a geologic repository. Non-TRU low-level waste (LLW) generated at the AFRs and at the fuel encapsulation facility is shipped to shallow land burial.

Fig. 2 illustrates an alternative to the basic spent fuel disposal case. In Case B the primary waste (i.e. encapsulated spent fuel) is placed in a very deep hole while the secondary



<u>Fig. 2.</u> Fuel Cycle Diagram - Case B
Spent Fuel in a Very Deep Hole

wastes (i.e. small amounts of intermediate and low level TRU waste) are still placed in the geologic repository. The diagram for Case C would be similar except that the encapsulated spent fuel is shipped to a designated sea port, placed on a special ship, transported out to sea, and emplaced in the sediments of the abyssal hills of the ocean floor.

The scope of the basic HLW case is shown in Fig. 3. Case D involves reprocessing the spent fuel and recovering and recycling the uranium and plutonium. It provides for the terminal disposal of encapsulated vitrified HLW, and other wastes generated during reprocessing, in a mined geologic repository. Again non-TRU LLW is shipped to shallow land burial. Unlike the spent fuel cases, the HLW cases require no AFR storage. It is assumed for economic reasons that the reprocessing of the fuel and extraction of uranium and plutonium would occur when the spent fuel has been out of the reactor one year. However, the encapsulated HLW would remain at the reprocessing facility for an additional nine years to satisfy repository acceptance criteria.

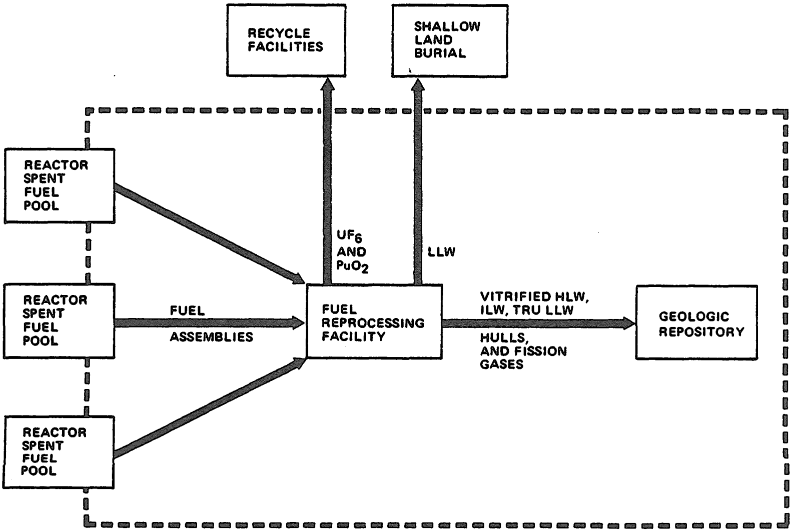


Fig. 3. Fuel Cycle Diagram - Case D
Vitrified HLW in a Mined Geologic Repository

Fig. 4 is an alternative to the basic HLW disposal case. In Case E the primary waste (i.e. encapsulated vitrified HLW) is placed in a very deep hole while the secondary wastes are still placed in the geologic repository. The diagrams for HLW Cases F, G, and H would be similar except that the primary waste is placed in a rock melting cavity, the subseabed and solar orbit, respectively. The primary waste form differs somewhat in two of these cases. In the rock melting concept, the processing facility is colocated with the repository, and the high level liquid waste is transferred directly from the processing facility to the underground cavity. In the space disposal concept, in order to achieve a high curie density, a special form of HLW is required and it will be placed in a spherically shaped container.

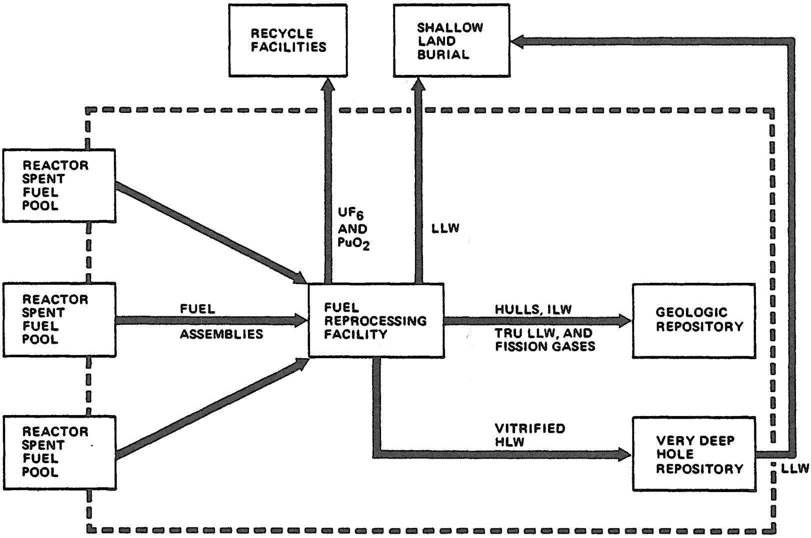


Fig. 4. Fuel Cycle Diagram - Case E
Vitrified HLW in a Very Deep Hole

ASSESSMENT APPROACH

Having defined the cases, the next step was to analyze and compare them in terms of six assessment criteria specified at the beginning of the study.

Radiological Impact

This assessment produced, for each study case, a relative measure of the radiation hazard to the public and to operating personnel due to the transportation, handling, processing and storage of nuclear waste during facility lifetimes and over the long-term. In doing this, very rough estimates of radiation dose values were developed. A risk assessment was not made. Rather, the values were estimated based upon established data for similar facilities and operations; they are measures of consequences only.

Non-Radiological Environmental Impact

This assessment examined the physical, biological, and socioeconomic effects of constructing, operating and decommissioning the facilities for each case. Six attributes were used in making the comparisons: water quality, meteorology and air quality, employment, land use, community facilities, and visual features. It compares cases on the basis of absolute magnitude of project impacts; site specific effects were not considered.

Degree of Development

This assessment produced for each study case a relative measure of confidence that the required spent fuel disposal systems can be designed, constructed and operated satisfactorily, based on the degree of development achieved by similar processes. Attributes used in making the assessment were: emplacement methods, emplacement medium, waste form, waste containment, and facilities.

Resource Consumption

In this assessment the water, energy, manpower, lost resources, materials, land, and capital required for case implementation were evaluated. Cases were compared on the basis of the number of resource consumption areas having significant impact on the national supply.

Safeguards

The ability of a safeguards system to provide and maintain a secure environment for the nuclear materials involved in each of the eight study cases was investigated. The relative impacts on the public from both sabotage and theft of nuclear materials were separately assessed.

Economics

A net levelized economic cost for each case was estimated on the basis of costs to society, without allowance for taxes, profit or insurance. Credits were assigned in appropriate cases for the value of recovered uranium and plutonium.

For any systems analysis, each criterion selected as a basis for evaluation should identify the differences between cases (if such differences do indeed exist) and each should be reasonably independent of the others (that is, there should be a minimum of overlapping influence). Within each criterion the generalized assessment approach used in this study involved, first of all, dividing each case into its logical facility components and transportation subsystems, and then developing for each a qualitative or quantitative measure of the penalty associated with that component. These values were then combined, using appropriate preference (or weighting) factors, into a composite assessment "measure" of that case. This general methodology was applied to each of the six assessment criteria with a fair amount of modification in some areas. No attempt was made to sum the assessments of the six individual criteria. The development of preference factors to enable this to be done is quite subjective, and was beyond the scope of this study.

CONCLUSIONS

Most of the disposal concepts evaluated in this study are not as well developed as the mined geologic repository concept. This created difficulty in the study, not only in defining finite waste management systems, but also in making the evaluations and comparisons of the cases. Some of the concepts have significant engineering problems that have not yet been adequately addressed. Others have unverified scientific bases. For this reason the assessments made should be considered at best preliminary.

Some of the criteria used in the assessments provided little basis for discriminating between cases (e.g. non-radiological environmental impact, safeguards impact, and short-term, abnormal radiological impact). Other criteria provided discrimination between processing concepts (i.e. spent fuel vs. HLW cases), but little discrimination between disposal concepts. The criteria that proved to be most effective in discriminating between cases were degree of development, resource consumption, and economics. As a result of the six assessments, the following tentative case ranking is made, with the cases listed from most desirable to least desirable:

(1) Case A or Case D, mined geologic repository

(2) Case C or Case G, subseabed disposal

(3) Case H, space disposal

(4) Case B or Case E, very deep hole

(5) Case F, rock melting

The ranking, which is nonlinear, is not intended to imply that any of the waste disposal concepts are inherently good or bad. Each has its positive and negative features. The ranking does, however, suggest a priority for further study. At least one, and possibly several, of the alternatives to a mined geologic repository may warrant further work. However, the design, construction and demonstration of the first geologic repository should not be deferred while the study of alternative concepts is pursued. The tentative case ranking, which is based on available technology, is discussed below.

Mined Geologic Repository Cases

Based on the results of this assessment, Cases A and D (mined geologic repositories) are judged to be the preferred methods for disposing of encapsulated spent fuel and HLW. Case A is superior or equal to the other schemes for spent fuel disposal except for long-term radiological impact. The very deep hole (Case B) and the subseabed (Case C) may provide greater radiological isolation, although the radiological impact of geologic repositories is considered to be quite low. Similarly, the mined geologic repository for the disposal of HLW (Case D) is preferred over other HLW disposal alternatives studied (Cases E to H). In the long term, however, the deep hole (Case E), the subseabed (Case G), and space disposal (Case H) may provide additional radiological isolation, thus reducing the already miniscule radiological impact associated with the mined geologic repository. This advantage is believed to be offset in all three cases by their negative features.

Subseabed Disposal Cases

Subseabed disposal (Cases C and G) shows the most promise after mined geologic repository (Cases A and D). The subseabed is rated ahead of the very deep hole in every area except possibly long-term, nonoccupational, normal radiological impact (because of a greater apparent pathway length, the very deep hole concept receives a better rating). The ratings are based on professional judgment rather than detailed analyses. Subseabed disposal (Case G) is superior to or equivalent to space disposal (Case H) in all assessment areas. It is also superior or equivalent to rock melting (Case F) in all assessment areas except resource consumption. Subseabed disposal has one area of significant resource impact, which is the difficulty expected in finding a suitable dedicated sea port.

Space Disposal

Disposal of HLW in space (Case H) shows the most promise after subseabed disposal (Case G). In two assessment areas, space disposal is superior to very deep hole and rock melting, i.e. long-term radiological impact and degree of development. In two other assessment areas that contribute to case differentiation, economics and resource consumption, the very deep hole and rock melting concepts are superior. Thus, space disposal as the third preferred disposal concept does not hold as strong a relative ranking position as that given to the mined geologic repository and subseabed disposal.

Very Deep Hole

Very deep hole is rated lowest of the three schemes considered for spent fuel disposal. It is ranked fourth after space disposal for the disposal of HLW. Very deep hole is ranked above or equal to rock melting in all assessment areas. It is ranked low primarily because of the extreme uncertainty of the claims made for the concept.

Rock Melting

Rock melting (Case F) is rated as having the lowest degree of development of any of the alternatives. It is not well defined, and the assessments were made based upon an assumed operating scenario. Not only the practical technology,but also the scientific basis needed to accurately explore this scheme, requires significant advancement. If the technical feasibility of rock melting could be demonstrated successfully, it might prove to be a worthwhile alternative to the mined repository.

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