UNRESOLVED TECHNICAL ISSUES FOR SHALLOW AND INTERMEDIATE DEPTH BURIAL OF NUCLEAR WASTE

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INTRODUCTION

The goal of nuclear waste management is to implement practices, procedures and methodology to assure long-term containment of nuclear waste and minimize exposure to both employees and the general public. To accomplish this requires knowledge of site selection, preparation, operation, decommissioning, and control or release after decommissioning. One area of research in waste management deals with shallow land burial.

Basically, the United States has two types of burial sites: the humid sites of the east and the arid western sites. The humid sites may emphasize research such as transport and migration whereas, the arid sites may emphasize site-specific erosion and bio-intrusion.

Shallow land burial of nuclear waste has proceeded in quantity amounts since the startup of the Hanford Engineering Works in 1944. In the United States, the majority of the burial to date has been "shallow land" which is at a depth of approximately 20 feet with 4 to 8 feet of soil cover. Since 1970, wastes defined as "transuranic" have been placed in a retrievable storage mode and covered with a few feet of soil. These materials are scheduled for retrieval within 20 years

after burial and destined for long-term disposal, possibly in deep geological media. The remaining nuclear wastes (which exclude transuranic radionuclides) have shorter half-lives and will decay to nontoxic levels within a manageable time period.

In December 1975, the Shallow Land Burial Steering Committee was chartered by the Waste Management Division of the Department of Energy (DOE) to examine the status of shallow land burial practices, recommend a program to eliminate deficiencies in the Division's program, and comment annually on the program's progress. [1] Committee members were selected from DOE sites and field offices recognized for their expertise on the subject.

The committee presented their first recommended plan in June 1976 [2] which was implemented with modest funding the following October. The plan was updated in September 1977.

In 1979, the committee was reassigned to provide technical advice on the preparation of the Low-Level Waste Management Technology Program Plan [1] by the Low-Level Waste Management lead site. In this capacity, the committee examines all activities relevant to DOE land burial sites and identifies technical areas requiring new or further research.

The current members of the Shallow Land Burial Steering Committee are:

J. L. Deichman, Committee Chairman, Rockwell Hanford Operations

R. B. Fitts, Recording Secretary, Oak Ridge National Laboratory

E. L. Albenesius, Savannah River Laboratory

R. L. Brodzinski, Pacific Northwest Laboratory

P. Colombo, Brookhaven National Laboratory

J. O. Duguid, Office of Nuclear Waste Isolation

J. L. Johnson, Los Alamos Scientific Laboratory

S. J. Phillips, Pacific Northwest Laboratory

E. M. Rommey, University of California - Los Angeles

J. G. Steger, Los Alamos Scientific Laboratory

T. Tamura, Oak Ridge National Laboratory

TECHNICAL ISSUES

Thirteen technical issues were identified by the committee.[1] In most instances, generic and/or site-specific technology development was already under way. The committee did not prioritize these items because it was determined that programmatic considerations (i.e., budget, political climate, environmental concerns, schedule impacts, etc.) could best be handled by program personnel who deal with these considerations on a daily basis. The 13 unresolved technical issues were classified into four major categories:

- Site (selection, characterization, modification).
- Waste (characterization, interaction with site).
- Operation (waste form, containment, assaying, emplacement, records).
- Performance evaluation (verification of predictions).

SITE

This category involves site selection, consideration of suitable engineering tradeoffs between complementary site characteristics, development of engineering methodology to provide enhanced site capabilities, engineered site performance improvements, assurance of long-term stability and evaluation of shallow versus intermediate depth burial.

Development of Techniques to Characterize and Improve Sites for Optimizing Burial Ground Performance

The objective of this research is to determine the optimum balance between complementary characteristics in selection of sites and to develop techniques for modification of site characteristics which enhance the containment of radioactive wastes.

A suitable balance must be maintained among complementary characteristics in developing site selection criteria (e.g., precipitation, runoff, erosion, infiltration, soil permeability, ground water table level, and soil sorptive capacity) to assure containment of radionuclides. Certain site properties may be altered to improve site performance.

Research should emphasize comparative studies of radionuclide movement from burial grounds having a range of climatic, edaphic, geologic and hydrologic conditions. Such studies permit evaluation of the relation between site characteristics and containment of buried waste. Experiments and field tests are needed to determine the feasibility of correcting local anomalies.

Development and Evaluation of Erosion and Intrusion Control Barriers

The objective is to develop and evaluate barriers which control erosional processes and the intrusion of flora and fauna into waste trenches.

The breakdown of waste-trench covers or seals may lead to a variety of problems, such as removal of radioactive materials from the burial site by wind or water erosion, by subsurface transport resulting from increased infiltration of precipitation, and by incorporation into flora and fauna in contact with waste trenches or with waste migrated from trenches.

Studies should be initiated to evaluate and develop effective barriers consistent with the abiotic, edaphic and biotic conditions at each burial site. The techniques used (e.g., natural vegetation and/or natural materials barriers) must be resistant to water and wind erosion, be effective in reducing infiltration of precipitation, remain stable over long periods of time, and be obstructive to burrowing animals.

Experiments should be conducted on the use of natural aggregate materials to develop the best methods for use at each site. A scenario, representative of each burial site, should be developed incorporating the ecological succession of events from initial site disturbance through operation and decommissioning.

Evaluation of the Technical Feasibility of Intermediate Depth Burial

The objectives are to consider the technical advantages of intermediate depth burial (IDB) compared to shallow land burial (SLB) and identify the steps required to demonstrate feasibility.

IDB has been proposed as a complementary alternative to SLB. IDB would position the waste further from plant root systems and fauna than does SLB and reduce the potential for intrusion by man. The increased depth of burial should be analyzed against the placement of more effective barriers in trench covers of conventional shallow depth trenches.

Suitable sites for IDB are more difficult to select than those for SLB and it's likely there will be increased operational costs associated primarily with excavation. The greater burial depth will reduce the distance between the waste and the water table. Because it appears that very little operational knowledge or experience exists about this concept, a thorough review should be made of IDB in both arid and humid regions. Promising concepts and alternatives should be evaluated and the most promising should be selected for further development and demonstration.

WASTE

The goal of this research category is to characterize the radiological, physical, and chemical properties of waste. Such properties determine interaction with the receiving site media and the degree of radiation exposure that may be received by employees and the public. This category deals primarily with the interactions of the wastes with the disposal medium (i.e., the site).

Determination of Mechanisms Controlling Water/Radionuclide Transport in Unsaturated and Saturated Zones

The objective is to quantitatively evaluate the mechanisms controlling water/radionuclide transport in natural burial media.

Near-surface media (e.g., soils) are invariably nonisothermal, nonisotropic, and nonhomogeneous, so that material transport is rarely simple. In partially saturated geohydrologic systems, radionuclide species are typically dissolved in an aqueous phase. However, radionuclides may be in the vapor or solid phase, depending on the burial conditions and the chemical species of the radionuclides. The relative distribution among these phases may change in both time and space.

Radionuclides can migrate in either liquid, gas, or solid form. The mechanisms causing migration under complex environmental conditions experienced at burial sites are not completely understood.

Models have been developed to evaluate mass and energy balance in the atmosphere and in geohydrologic systems. However these models do not adequately simulate the migration of radionuclides and water in the geohydrologic system. The inadequacy of simulation is predominantly due to a paucity of information concerning the mechanisms influencing transport. Furthermore, most models need to be validated.

Quantitative information is needed on the interaction of the waste and the disposal medium to evaluate three-dimensional transport of fluids, gas, particulate matter and radionuclides and for their evaluation using existing predictive models.

Determination of the Effects of Organic and Inorganic Complexation on Transport of Radionuclides

The objective is to determine the importance of the effect of complexing agents on the transport of radionuclides through the ground.

Large quantities of organic wastes (e.g., scintillation liquids, solvents, and liquids used for decontamination) are disposed of in SLB trenches. Many of these organic chemicals are complexing agents which can affect the leachability, solubility, and movement of radionuclides and toxic heavy metals. Inorganic complexes may also be formed and play an important role under appropriate chemical conditions.

Literature and field surveys should be undertaken to determine the types and quantities of complexing agents disposed of in SLB trenches and to identify and assay the radionuclide complexes present in trench leachates and within the geologic formations. The mechanisms and extent of interaction of these complexes with the media should be determined and the effect on retardation established.

Determination of Sorptive Capacities for Radionuclides in Soil/Solution Systems

The objectives are to identify parameters and mechanisms affecting radionuclide sorption in soil/solution systems and measure the extent of their impact.

The mechanisms and degree of interaction between radionuclides in ground water and soil materials depend to a great extent on the predominant chemical and physical forms of the radionuclides in the waste and in the receiving geologic media. The chemical and physical forms are affected by a number of chemical conditions (e.g., electrolyte concentration, oxidation-reduction conditions, pH, presence of complexing agents) which may be variable in both time and space.

Sorptive coefficients provide an index of the degree of interaction between the radionuclide and the soil material and are affected by a number of parameters. Sorption coefficients should be determined using soil materials and ground water as they actually exist at specific sites. Parameters affecting sorption coefficients should be evaluated.

Measurement of sorption coefficients is not sufficient to characterize the mechanisms of the interaction and thus does not provide an adequate basis for predicting radionuclide retardation in the formation. This requires detailed studies of the mechanisms of the interaction and retardation mechanisms; such studies are particularly important for the more hazardous and long-lived radionuclides.

Determination of the Effects of Soil Microorganisms on Transport and Transformation of Radionuclides

The objective is to determine the effects of microbial action on the (1) solubility, (2) mobility, and (3) bioavailability of radionuclides in SLB sites.

Soil microorganisms are known to solubilize various chemical elements in the soil by production of organic and mineral acids and other byproducts which may form complexes with radionuclides or may alter the chemical conditions of the solution, such as pH, which affect solubility. Soil microorganisms are also capable of transforming organic wastes into gaseous

products. Conversely, microorganisms may degrade organic material, reducing organo-radionuclide complexation and enhancing the retardation of the radionuclides. Chemical and physical changes mediated by soil microorganisms may influence the bioavailability of radionuclides.

Sampling should be conducted at selected disposal sites to identify and quantify the soil microorganisms present. Laboratory studies should be conducted using soil materials and trench leachates from selected sites innoculated with typical soil microorganisms to identify the reaction mechanisms of microorganisms with radionuclides. Products of microbial interaction with the wastes should be identified to evaluate the potential effects on radionuclide migration and bioavailability.

Determination of the Potential Hazards from Long-Lived Radionuclides

The objective is to determine the amount of long-lived radionuclides disposed of in low-level solid wastes and the significance of their contribution to the potential dose to man.

Some radionuclides (e.g., ^{14}C, ^{59}Ni, ^{63}Ni, and ^{99}Tc) have half-lives which are long, relative to the projected period of active maintenance and administrative control of a decommissioned burial site. It is necessary to assess the probability of their transfer in time via various environmental pathways into man. If such studies indicate a significant potential radiation dose is possible, limits should be derived for the concentration and quantities of long-lived radionuclides to be permitted in SLB or IDB.

OPERATION

The goal of the work in this area is to develop technology for improved containment of the waste for the lifetime of the burial facility and as long afterward as the waste presents a potential radiological hazard. This category includes methods used to operate burial sites, provide packaging criteria, perform acceptance inspection of waste, emplace the waste forms, develop and record site inventories, increase the term of site usefulness, correct existing site deficiencies, and prepare the site for decommissioning.

Development of Methods to Prevent or Minimize Structural Failures of Trenches

The objective is to develop methods to prevent or minimize structural failure of waste trenches.

At several disposal sites, trench caps have failed due to the formation of voids as the waste and waste packages deteriorate and then compact . Failure of the trench cap allows excessive infiltration of precipitation and destroys the effectiveness of any biobarrier that may have been installed, resulting in increased rates of radionuclide migration and a safety hazard to operations staff.

These failures could be prevented or ameliorated by compacting the waste in situ to reduce void volumes, improving the cap strenth, providing better structural support for the cap, or using standardized modular containers containing compacted waste which permit compact stacking.

Techniques should be developed and field tested for improving the structural integrity of waste trenches. Candidate techniques include soil compaction, injection of solidifying materials into the void volume of trenches, and addition of expanding clays into waste trenches.

Development of Instrumentation to Verify Waste Receipts

The objective is to develop instrumentation for the assay of waste receipts providing verification of the contents of the package and improving the authenticity of the records of materials buried.

Present records frequently provide insufficient information about the radiological, physical and chemical characteristics of waste package contents received for burial to permit prediction of the long-term behavior of the waste in burial grounds. Improved instrumentation and measurement techniques are needed to provide the disposal site operator with the capability of verifying that the contents of the waste package conform to the properties required to be listed on standard burial forms.

Although instrumentation capable of quantitative assay of all conceivable packages may not be possible, primary emphasis should be placed on development of versatile techniques for assay of the more important parameters. A continuing effort will be required to modify new instruments as they are developed.

Development of Operational Practices to Minimize Reliance on Postoperational Control and Surveillance

The objective is to develop operational practices for SLB of radioactive wastes that will minimize the need for post-operational control and surveillance which will enhance site decommissioning.

A potential radiological hazard from buried waste persists for a considerable period beyond the time when wastes are emplaced. Unrestricted decommissioning of the site will not be permissible until it can be shown that further control and surveillance are no longer required.

Suitable operational practices should be developed and demonstrated for use during the active operational stages of the site that will minimize the postoperational time period that continued control and surveillance will be required. These practices should be designed to ensure that buried waste is protected from erosion, leaching, infiltration, biological cycling, and intrusion and/or exhumation until radiation levels have decayed to non-toxic levels.

Criteria establishing the type and form of waste (including packaging) appropriate for burial, depths and dimensions of burial trenches, and trench capping are needed to assure operational practice.

PERFORMANCE EVALUATION

The goal of research in this area is to develop procedures for evaluating past and current performance and for predicting continuing performance of a waste disposal facility. This category includes the activities required to establish monitoring techniques for evaluating site performance and to develop and verify predictive models.

Development of Methodology and Equipment for Monitoring Burial Sites

The objective of this technical issue is to develop monitoring methodologies and instrumentation for evaluating present and projected containment of radionuclides at waste burial sites.

Performance assessment of a burial site requires field operational analytical systems capable of measuring water and radionuclide transport in the geohydrologic and atmospheric systems. Factors typically affecting water and radionuclide transport include: (1) micrometeorology (e.g., precipitation, evaporation, solar radiation, humidity, temperature), and (2) geohydrology (e.g., temperature, humidity, water content, cation-anion water concentration, redox potential, pH). These parameters are interactive within a complex three-dimensional continuum consisting of the waste burial formation and the atmosphere.

Monitoring of parameters directly affecting water migration (the principal agent for transport of radionuclides within and from burial sites) and radionuclide migration should be conducted. Criteria and performance standards should be developed so that predetermined remedial action measures are implemented when "trigger" levels are reached. Improved monitoring techniques and instruments should be developed and demonstrated and efforts continued to further upgrade monitoring systems. Attention should be given to development of statistically sound programs for operational and postoperational monitoring systems.

Integration and Verification of Models for Evaluation of Waste Burial

The objective is to develop and verify models suitable for an integrated, systematic evaluation of waste burial sites and operations.

Performance evaluation of a burial site requires an integrated assessment of preoperational and postoperational characteristics and practices affecting containment of the waste. Waste management consists of a complex system of

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operational procedures (e.g., site engineering, trench construction, site stabilization, site maintenance, waste receiving, waste segregation, waste emplacement) which interact with the characteristics of the site (e.g., meteorologic, geohydrologic, biologic) to influence the performance of the system.

Additional complexities are introduced by interactions of the waste within the primary waste matrix, the geohydrologic formation, the atmosphere, and the biosphere. An adequate performance evaluation of such a complex, interrelated system requires an integrated, systematic approach. The validity of the evaluation further requires that the models for individual pathways or processes be adequately verified.

ISSUES NOT RECOMMENDED AT THIS TIME

Four additional issues were considered and were identified as not recommended at this time because of complexity or lack of cost-benefit.

1. Effect of Off-Normal Weather Conditions on Burial Sites

2. Determination of the Effects of Trench Construction on Geohydrological Parameters

3. Development of Instrumentation for In Situ Physical/ Chemical Characterization of Buried Waste

4. Documentation of Burial Practices

REFERENCES

1. ORNL/NFW - 79/62, "Unresolved Technical Issues in Land Burial of Low-Level Radioactive Waste," Shallow Land Burial Steering Committee - J. L. Deichman, Chairman, October 1979.

2. "The DOE Plan to Develop and Improve Technology for the Shallow Land Burial of Solid Low-Level Radioactive Waste," Shallow Land Burial Steering Committee - J. G. Steger, Chairman, October 1976.