PROTECTIVE BARRIER SYSTEMS FOR FINAL DISPOSAL OF HANFORD WASTE SITES

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ABSTRACT

A protecting barrier system is being developed for potential application in the final disposal of defense wastes at the Hanford Site. The functional requirements for the protective barrier are control of water infiltration, wind erosion, and plant and animal intrusion into the waste zone. The barrier must also be able to function without maintenance for the required time period (up to 10,000 yr). This paper summarizes the progress made and future plans in this effort to design and test protective barriers at the Hanford Site.

INTRODUCTION

The Hanford Defense Waste-Environmental Impact Statement (HDW-EIS) currently being prepared will present an evaluation of alternatives for the disposal of high-level, transuranic, and tank wastes currently located at the Hanford Site. Three alternatives are being evaluated: geologic disposal, in-place stabilization and disposal, and a reference alternative (which represents a combination of these alternatives depending upon the waste form). Each of these alternatives takes into consideration the use of protective barriers in order to meet regulatory requirements for waste confinement.

The functional requirements for the protective barrier are control of water infiltration, wind erosion, and plant and animal intrusion into the waste zone. The barrier must also be able to function without maintenance for the required time period (up to 10,000 yr).[1] A system of surface and subsurface markers would be used in association with the barrier to deter human intrusion by providing suitable, redundant warning messages. The subsurface marking systems are emplaced within the barrier.

The approach taken to date in protective barrier development includes activities in the following areas:

- Preconceptual Design
  - The definition of barrier functional requirements.
  - The comparison of barrier concepts on the bases of cost, feasibility, constructability, and the ability to meet waste confinement criteria.
  - The identification and definition of a barrier preconceptual design for further evaluation.
- Field and Laboratory Studies
  - The construction and monitoring of barrier comparison field-test plots using identified barrier types.
  - The preliminary design of lysimeter, erosion control, and animal intrusion field test facilities to test identified barrier configurations under simulated, accelerated environmental conditions, such as increased rainfall.
  - The initiation of studies on the effects of earthquake, range fire, climate change, and other natural events on barrier performance.
  - The evaluation of selected geologic structures analogous to barrier concepts of interest.
- Performance Evaluation
  - The simulation of water infiltration identified barrier types using numerical models, particularly with reference to the ability of the barrier to control water infiltration.

Some of these activities are further along than others. Plans specify completion of currently identified activities within a minimum of 5 yr. This paper summarizes the progress made and describes in some detail the remaining efforts to develop a barrier system.

CONCEPTUAL DESIGN OF PROTECTIVE BARRIERS

More than 20 barrier concepts have been compared on the bases of cost, material durability, constructability, and the ability to meet waste disposal criteria.[2] The concepts included impermeable barriers such as concrete slabs, barriers with asphalt layers, and barriers with clay and salt layers. Massive soil barriers (mounds) and mounded rock riprap barriers were also considered. A number of multilayer barrier configurations consisting of layers of soil, sand, geotextile, gravel, and rock were also included in the comparative studies. Based upon these studies, natural analog studies, and the limited use of numerical models to assess the ability of the barriers to control water infiltration to the waste zone, a multilayer "reference" barrier was identified for further development.[3] The protective barriers being developed for existing waste sites are above grade. It does not appear feasible to apply at-grade or below-grade barriers for existing waste sites, due to the cost and risk of excavating in contaminated zones. Continued barrier development efforts have resulted in increased refinement and definition of detail of the multilayer design concept.

PROTECTIVE BARRIER FIELD TESTS

Although the focus of barrier development has shifted to the multilayer barrier, based on preconceptual studies, small field-test plots of the multilayer and other barrier designs have been constructed for comparative purposes.[4] Barrier designs, other than multilayer, are being tested in order to validate that computer modeling will correctly predict performance. The barrier test plots are truncated, circular mounds and are designed to monitor, evaluate, and compare performance under field conditions. The test plot design enables two-dimensional numerical modeling of each barrier configuration. Five barrier test mounds have been constructed, including mounded rock, impermeable off-flow, mounded soil, and two variations of the multilayer barrier type. The test plots are illustrated in cross section in Fig. 1. After construction, the surface of each test barrier was left untreated in order to evaluate erosion, encroachment of plants and animals, and water infiltration under unvegetated conditions.

The two multilayer barriers are constructed approximately 2.5-m above grade. The barrier shown in Fig. 1d is designed to control water infiltration, and the barrier in Fig. 1e is designed to control biotic intrusion. The mounded soil barrier (Fig. 1a) consists of approximately 3 m of mixed native soil and sand constructed above grade. The rock barrier design (Fig. 1b) consists of a 2.5-m-high mound of two types of large rock: angular basalt and rounded, gravel material. Figure 1c illustrates the surface impermeable barrier with water off-flow design.

Several instrumentation systems monitor barrier performance in each plot. Some of the instrument systems extend to just above the simulated waste zone beneath the barrier. Each test barrier is instrumented with transducers capable of measuring moisture content, temperature, density, and particulate filtration (i.e., the infiltration of the upper soil layers of the barrier down into the coarse-rock layers below). The microclimate in the vicinity of each barrier is monitored with meteorological instruments. Temperature, relative humidity, wind velocity, predominant wind direction, dew duration, and soil erosion parameters are determined at different locations and elevations, and over specific time intervals.

Test barriers are visually inspected to determine the intrusion of plants and animals. In addition, lithium chloride (LiCl) and cobalt chloride (CoCl) inorganic tracers were placed in each barrier at specific layer interfaces or at the original construction grade. These tracers, if translocated to the ground surface, can be evaluated by photometric methods to determine plant uptake and dispersion. Zinc sulfide (ZnS) and colored pigments were placed in or below each barrier to determine dispersion by animals. These are visually identifiable at the ground surface and can be seen with ultraviolet light.

Preliminary analyses of barrier performance in these field tests indicate that a mounded soil barrier would fail to prevent moisture drainage into the underlying waste zone before it could be evapotranspirated. Moisture drainage into the waste zone is also postulated as a failure mechanism of the mounded rock barrier. Observations of mounded rock barrier performance also indicate significant rates of deposition of airborne particles into the interstitial rock space, plant and animal encroachment, and moisture accumulation at or near construction grade.

The performance of the impermeable off-flow barrier design is unacceptable because precipitation and snow melt accumulate under the barrier. The inability of the barrier to permit evaporation of moisture is postulated as the cause of the water accumulation below the barrier.

Evaluation of the multilayer infiltration control barrier to date indicates that the design is generally adequate for control of water infiltration; however, burrowing animals and deep-rooted plants may disturb the sand and geotextile layers underlying the soil. A significant disturbance of these layers could reduce the ability of the barrier to control water infiltration. Conceptually, the multilayer biotic intrusion control barrier may be adequate for moisture storage under most conditions. However, with increased rainfall expected in a wetter climate, movement of water through the coarse-rock layer may occur. In addition, reduced flux of vapor phase water back through this layer may result in unacceptable water accumulation in the waste zone.

Because of observed and postulated problems with the test barrier designs constructed to date, further development has continued, particularly with regard to the promising multilayer barrier type.

PROTECTIVE BARRIER PERFORMANCE SIMULATION

One- and two-dimensional simulations using numerical models have been used to evaluate water infiltration through various multilayer barrier configurations.[5,6] Simulations were done using current normal rainfall conditions as well as repetitive 100-yr maximum rainfall rates. One-dimensional simulation results indicate that evapotranspiration is a critical process in the ability of the barrier to control water infiltration. A uniform cover of plants on the barrier surface was found to be essential. Soil properties also are controlling factors in barrier performance. A fine-textured, silty soil (i.e., with greater than 30% passing a 75-μm screen) is essential. Rock fragments (rock mulch) admixed into the upper 30 cm of the soil layer in the barrier also influence infiltration control capabilities. (Such an admixed layer is included in the multilayer design to control wind erosion.)

To date, barrier performance simulation activities have shown that multilayer barrier concepts are adequate to control water infiltration to the waste zone even if a change to a wetter climate is assumed. However, the modeling has also indicated the need for

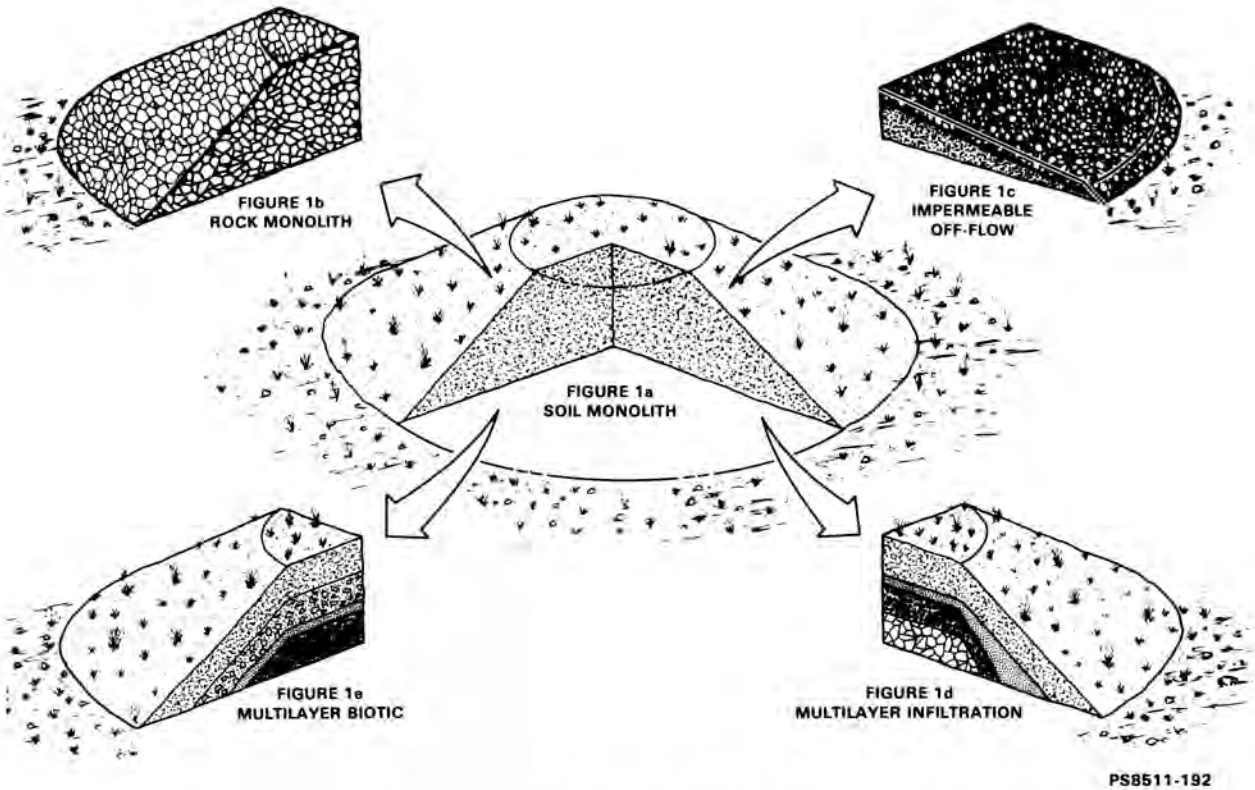

Fig. 1. Generalized Representation of Five Types of Test Barriers Constructed for Comparison of Performance.

a vegetated barrier surface and the need to control the depth, texture, and composition of the soil used in the upper layer of the barrier. Because of these findings, optimization of the multilayer barrier design has continued.

OPTIMIZATION OF THE MULTILAYER BARRIER DESIGN

As a result of progress made in barrier development, particularly in the area of barrier performance simulation, greater definition of design detail is possible for the multilayer design concept. An additional field barrier test plot is planned for construction and will incorporate these design refine ments. In addition, field lysimeter and wind erosion test facilities are being designed to evaluate this advanced barrier and to provide data for model validation. For instance, the increased rainfall that might be expected from a climate change can be simulated at the lysimeter facility, and the ability of the barrier to adequately function can be verified. Biotic intrusion tests and the erosive response of rock mulches to wind can also be done at the facility.

The advanced multilayer design, as it currently is conceived, consists of the following components, beginning at the top surface of the barrier and proceeding downward:

- Native, silty soil containing pebbles admixed into the top 30 cm of soil
- A single layer of 25-cm-diameter basalt near the base of the silty soil
- A layer of clean, washed sand configured between two layers of geotextile (0.2- to 0.7-cm-diameter sand grains)
- An optional impermeable layer or membrane of very low hydraulic conductivity
- A rock layer of basalt ranging in size from 1 to 25 cm in diameter.

The complexity of this barrier would require construction practices similar to those used to construct interstate highway roadbeds. (Figure 2 illustrates the design of this barrier.)

Specific barrier layers work as a system to control potential radionuclide transport. Large rock is used in the lower part of the barrier as a deterrent to plant and animal intrusion. Smaller diameter basalt particles are distributed in the interstices of the larger rock to act as filter material to reduce downward movement of fines from overlying layers. The fine-woven glass-fiber geotextiles serve as a filter during construction, in addition to the rock filter. The rock filter also serves as a capillary break between the underlying coarse-rock layers and the overlying silty-soil layers. As a result, infiltrating water will be held near the upper soil layer of the barrier where it can be evapotranspired to the atmosphere.[7,8] The textural break in materials provides the fundamental principle upon which the barrier cycles water.

The silty soil forming the uppermost part of the barrier serves several purposes. The hydraulic

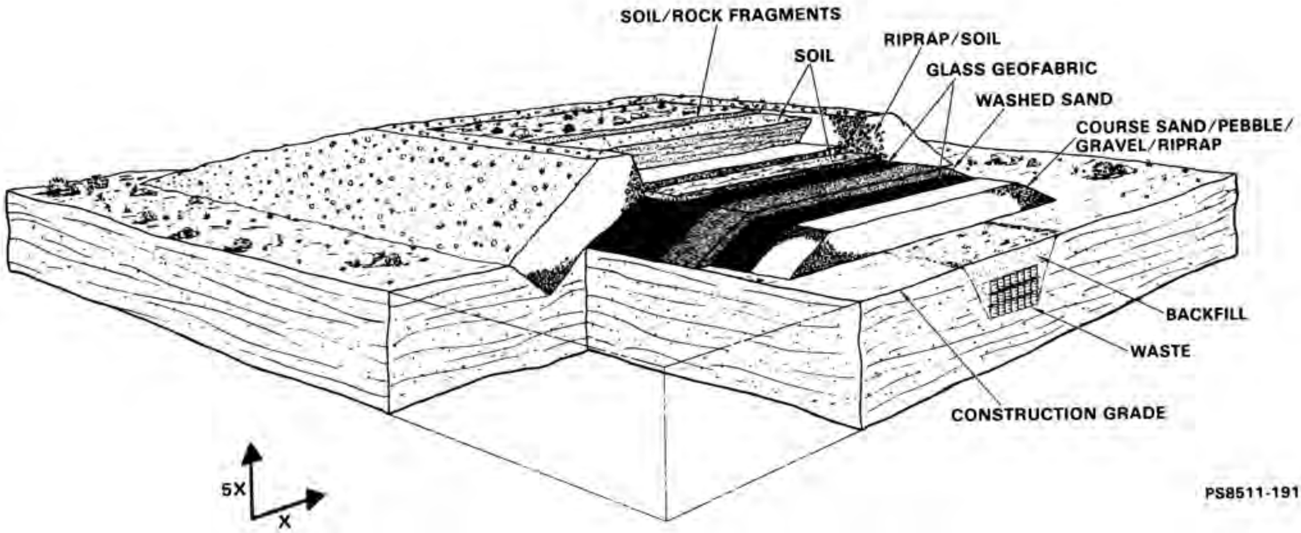

Fig. 2. Representation of a Multilayer Barrier Constructed Over a Hypothetical Waste Disposal Site (trench). Figure is vertically exaggerated for clarity.

properties of this material permit storage and a medium for rooting of transpiring plants. A single layer of rock near the base of the soil layer inhibits burrowing animals from disturbing the physical integrity of the soil to sand interface located below the soil layer. Additionally, the soil layer contains small, gravel particles mixed into the soil surface layer (rock mulches). This material serves to control wind erosion by forming a stable surface capable of withstanding the effects of strong, sustained winds.

SINGLE-SHELL TANK DISPOSAL TECHNOLOGY TEST

A test of the multilayer barrier is planned for application to a tank farm at the Hanford Site.[9] The domes of the tanks in the 241-TY Tank Farm, a six-tank farm with relatively low volumes and concentrations of radionuclides, will first be filled with basalt gravel. Following a period of waste/fill monitoring via instrument strings deployed in the tanks, a protective barrier/marker system will be placed over the farm. This test will represent the first placement of the multilayer barrier over an actual waste site and will provide information on the safety and cost effectiveness of the concept.

CONCLUSIONS AND FUTURE PLANS

Information to date tentatively indicates that the multilayer barrier design may provide effective, long-term protection for radioactive waste. Additional evaluations and development activities are underway to confirm the ability of the design to perform as intended and to validate the numerical models used to simulate barrier performance.

During fiscal years 1986 and 1987, laboratory and field testing activities related to moisture infiltration, plant and animal intrusion, physical stability, and erosion control will be designed and constructed. Data will then be collected and activities refined, depending on their specific nature, through fiscal year 1989. Numerical models used to simulate barrier performance will be validated with accumulated data by fiscal year 1990, to be followed by final design and documentation. Current plans call for all barrier development tasks to be completed and all issues closed by the end of fiscal year 1991.

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