FIELD EVALUATION OF GEOLOGIC MATERIALS TO LIMIT BIOLOGICAL INTRUSION OF LOW-LEVEL WASTE SITE COVERS

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ABSTRACT

The long-term integrity of low-level waste shallow land burial sites is dependent on the interaction of physical, chemical, and biological factors that modify the waste containment system. Past research on low-level waste shallow land burial methods has emphasized physical (i.e., water infiltration, soil erosion) and chemical (radionuclide leaching) processes that can cause radionuclide transport from a waste site. Biological intrusion of low-level waste trenches has generally been considered to be of secondary importance despite mounting evidence to the contrary.

Preliminary results demonstrate that a sandy backfill material offers little resistance to root and animal intrusion through the cover profile, while bentonite clay, cobble, and cobble-gravel combinations do reduce plant root and animal intrusion through cover profiles. However, the bentonite clay barrier system appears to be altered by plant roots through time. Desiccation of the clay barrier by invading plant roots may limit the usefulness of this material as a moisture and/or biological barrier unless due consideration is given to this interaction.

INTRODUCTION

Low activity wastes and wastes suspected of being contaminated are generally buried in shallow trenches (1.5 to 45 m wide, 2 to 11 m deep, 6 to 300 m long) that are covered with less than 1.0 to 2.5 m of material when the trenches are full.[1] Most waste burial facilities attempt to revegetate the trench covers to minimize soil loss and to increase aesthetic appearance of the site. Although it has been recognized[2,3] that biological intrusion of low-level waste trenches can lead to transport of radionuclides from a burial site, little has been done to quantify the magnitude of the problem and to develop measures, when needed, to prevent the intrusion.

The stability of low-level waste trench covers is a function of physical, chemical, and biological factors that interact in both obvious and subtle ways. The importance of biological factors in altering the integrity of trench covers is often overlooked despite evidence that plants and animals can influence trench cover stability and, as well, can mobilize radionuclides buried in the trench.[4-7] Biological interactions with trench covers can be direct, as in the case of radionuclide uptake by plant roots, or they can be indirect, such as when tunnel systems created by burrowing animals increase the rates and depths of rain water penetration into the trench cover profile.

The purpose of this paper is to describe short-term, small-scale field experiments at the Los Alamos Experimental Engineered Test Facility that evaluate the effectiveness of several geologic materials in minimizing biological intrusion through low-level waste trench covers. In addition, preliminary results are presented on the effectiveness of various barrier materials.

Natural geologic materials were chosen for testing over man-made materials (e.g., chemicals or asphalt) to ensure a long environmental life of the barrier material. Past studies suggest that man-made materials lack stability after exposure to environmental conditions longer than about 25 years.[8]

METHODS AND MATERIALS

A series of experiments was initiated at Los Alamos in the Experimental Engineered Test Facility to determine the effectiveness of several geologic materials as barriers that inhibit plant and animal intrusion into low-level waste cover profiles. Initial plant root barrier experiments employed 288 lysimeters consisting of 25-cm-diameter PVC pipe ranging from 105 to 210 cm in length. Cover profiles were constructed in the lysimeters to evaluate the effect of four different variables on plant root penetration with depth (Table I). The profiles, as shown by the example in Fig. 1 consisted of a simulated waste (CsCl) at the bottom of the profile. The waste layer was covered by a barrier layer consisting of four different types of geologic materials

TABLE I

EXPERIMENTAL DESIGN OF PLANT ROOT INTRUSION STUDY

VARIABLE	NUMBER	REMARKS
Plant Species	3	Barley, Clover, Alfalfa
Top Soil Depth	2	30 cm, 60 cm
Barrier Type	4	Crushed Tuff Bentonite Clay Cobble Cobble–Gravel
Barrier Depth	3	Clay: 15 cm, 30 cm, 45 cm Others: 30 cm, 60 cm, 90 cm
Replications	4	
Total Number	288	

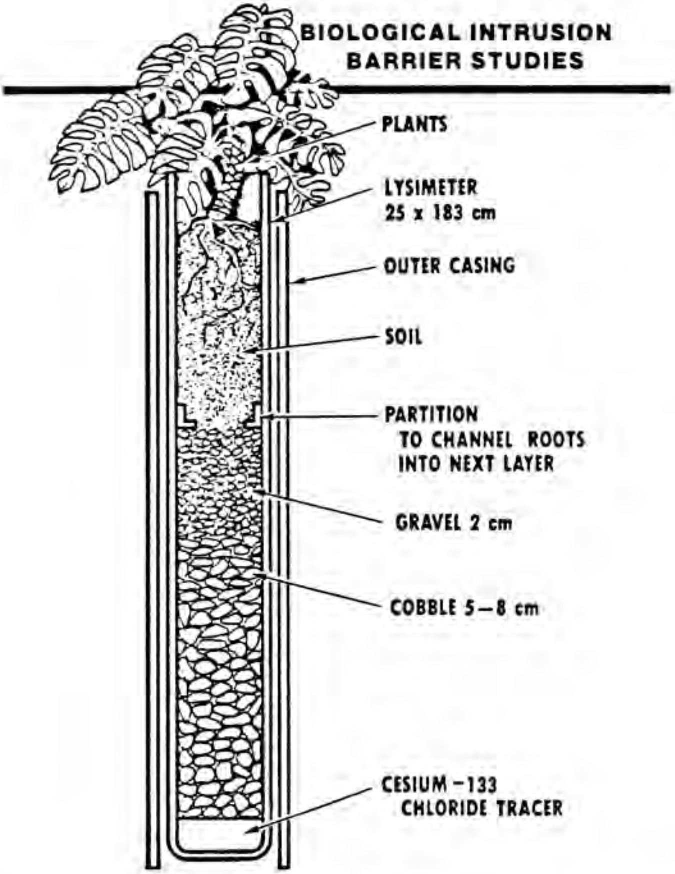

Fig. 1. Experimental Soil Profile Configuration Used to Evaluate Geologic Materials as Root Intrusion Barriers

(cobble, cobble-gravel, bentonite clay, and crushed tuff) at three different depths. Top soil was applied at two different depths as an overburden to complete the profile. Three species of fast-growing, deep-rooted plants (alfalfa, barley, yellow sweet clover) were seeded into the lysimeters to produce the biological stress on the barrier system.

Low-level waste trenches at Los Alamos are cut into a welded volcanic ash called tuff. During and after the filling of the trenches, tuff that has been pulverized by the heavy excavation equipment is used as a backfill and final covering. Crushed tuff used in the plant root intrusion study was obtained from stockpiles at the Laboratory's operational low-level waste site.

The bentonite clay used in this study was purchased as a commercial product called Aquagel (NL Baroid/NL Industries, Inc., P. O. Box 1675, Houston, TX 77001). This Wyoming bentonite is a colloidal clay (aluminum silicate) composed chiefly of montmorillonite with a high swelling capacity in water. Before placing the clay barrier layer within the profile, the dry clay was mixed with water at a rate of about 1:10 by weight.

The cobble was obtained locally and consisted of washed and screened material ranging from 5-8 cm in diameter. The cobble-gravel barrier material consisted of the 5-8 cm diameter cobble overlain by 1-2 cm diameter washed gravel. The purpose of the gravel layer over the cobble was to retard infiltration of soil into the spaces between the cobble. The presence of soil in the cobble barrier likely provides a channel for root migration downward through the profile.

Conditions in the lysimeters were optimized for plant growth to produce maximum stress on the barrier systems. The soil was amended with organic matter (steer manure) and commercial fertilizer (0-46-0); plants were watered in excess of the field capacity of the topsoil overlying the profile.

A companion study was also initiated to evaluate the effectiveness of the barrier systems in inhibiting animal burrowing with depth. Four galvanized metal culverts (1.9 m diameter by 2.2 m height) were placed on end and filled with an experimental waste cover profile consisting of one of the barrier materials covered by top soil. A pocket gopher (*Thomomys bottae*), a highly active burrowing animal, was introduced into each culvert and was allowed to construct a burrow system within the cover profile.

Barrier penetrations were evaluated throughout the growing season by analyzing plant tissue for stable cesium in the case of the lysimeter study, and by physically mapping the plant root and animal burrow systems in the cover profile at the conclusion of the experiment. The biological intrusion barrier studies are one of several studies being conducted in the Los Alamos Experimental Engineered Test Facility (see paper by DePoorter, Abeele and Burton - this symposium). The purpose of these studies is to design and evaluate integrated barrier systems that are effective in limiting erosion, moisture infiltration, and biological intrusion of low-level waste cover profiles.

PRELIMINARY RESULTS

Plant Root Barriers

Initial results based on the cesium content of vegetation samples indicate that 144 of the 288 cover profiles had been penetrated by plant roots in a 102-day period. Analyses of these data by experimental variable show that about 51% of the penetration through the barrier materials was caused by barley, whereas clover and alfalfa were each associated with about 24% of the penetrations. Initial differences in the rate of root penetration by plant species indicate the need to carefully consider rooting characteristics of species used to stabilize low-level waste covers. Consideration must also be given to the rooting characteristics of successional species that eventually replace the plants used to reclaim low-level waste sites.

The relationships between barrier penetrations and barrier type, barrier depth, and soil overburden depth are presented in Tables II-V. Nearly all (69 out of 72) of the profiles containing a sandy backfill material (crushed tuff) had been penetrated by plant roots after 102 days regardless of barrier or soil depth. About 33% (24 out of 72) of the cobble barrier systems and about 44% of the clay and 26% of the cobble-gravel systems had been penetrated after 102 days. Minimum barrier and soil depth combinations were associated with the highest rate of root penetrations through the clay, cobble, and cobble-gravel; increasing soil and barrier depth substantially reduced barrier penetrations. The most effective depth combination after 102 days appears to be 60 cm of soil and 90 cm of barrier, although statistical analysis of the data at the conclusion of the experiment may reveal that other depth combinations were equally effective.

While bentonite clay and cobble-gravel performed equally well in preventing plant root intrusion, plant roots greatly altered the integrity of the clay barrier system. During the course of the study it was noted, by visual observation in clear lucite lysimeters, that the integrity of the clay layer changed through time. A gradual, but continual, shrinkage of the clay layer occurred as a result of depletion of moisture

TABLE II

NUMBER OF ROOT PENETRATIONS THROUGH CRUSHED TUFF BARRIER MATERIAL AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	12[a]	12	12	36
60	12	12	9	33
Total	24	24	21	69

[a]The maximum sample size for each cell is 12.

TABLE III

NUMBER OF ROOT PENETRATIONS THROUGH COBBLE BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	9*	3	3	15
60	4	3	2	9
Total	13	6	5	24

*The maximum sample size for each cell is 12.

TABLE IV

NUMBER OF ROOT PENETRATIONS THROUGH BENTONITE CLAY BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	15	30	45	Total
Soil Depth (cm)				
30	12*	9	2	23
60	7	2	0	9
Total	19	11	2	32

*The maximum sample size for each cell is 12.

TABLE V

NUMBER OF ROOT PENETRATIONS THROUGH COBBLE-GRAVEL BARRIER MATERIALS AS A FUNCTION OF BARRIER AND SOIL DEPTH AFTER 102 DAYS

Barrier Depth (cm)	30	60	90	Total
Soil Depth (cm)				
30	5*	4	2	11
60	3	4	1	8
Total	8	8	3	19

*The maximum sample size for each cell is 12.

from the clay by invading plant roots. This observation, if confirmed by further data, has significant implications on the use of bentonite clay as a moisture, gas, and/or biological barrier.

Animal Intrusion Study

Tunnel systems created by pocket gophers in the four metal culverts were mapped by injecting each system with an expanding polyeurethane foam. Excavation of the tunnel casts revealed that the sandy backfill (crushed tuff) offered little resistance to the burrowing activities of pocket gophers whereas bentonite clay, cobble, and cobble-gravel barrier systems all prevented gopher burrowing with depth. Gophers were physically unable to move cobble 7.5-12 cm in diameter. While gophers could transport gravel (~1-2 cm in diameter) to the ground surface, tunnels created in the gravel were unstable and collapsed thereby preventing unrestricted movement of gophers in this zone. Bentonite clay, because of its consistency, discouraged gopher tunneling. However, the action of plant roots in drying the clay may change the ability of gophers to tunnel in this material.

FUTURE STUDIES

The small-scale plant root intrusion study will be concluded by sampling each lysimeter to determine root biomass versus depth within the profile. Although none of the root barrier systems may prove 100% effective, certain of these systems may greatly reduce root biomass with depth and thereby reduce the potential for contaminant uptake.

Further studies in the small-scale lysimeters will focus on the effect of plant roots on the integrity of clay barrier systems. A variety of clay types suggested for use in large volume waste reclamation methodologies will be evaluated under various experimental conditions. These conditions include clay barrier depth and position within the profile under various moisture regimes. The results of this experiment will provide data useful in selecting clay materials that are effective as moisture, gas, and biological barriers.

Biological intrusion studies will be initiated at intermediate scales in the *caissons* at the Experimental Engineered Test Facility (see paper by DePoorter, Abeele and Burton - this symposium). In addition to providing performance data for biological barrier materials at larger scales, these studies will relate the influence of barrier materials on moisture regimes within the cover profile.

Best estimates of effective biological barriers will be evaluated on a low-level waste trench at Area G, the Laboratory's current low-level waste disposal site. The emphasis of the experiment will be on evaluating barrier effectiveness under actual site operating conditions using native grass species for ground cover and with natural precipitation.

SUMMARY

Preliminary results from small-scale, short-term biological intrusion studies at the Los Alamos Experimental Engineered Test Facility show that sandy backfill material is readily penetrated by invading plant roots and animals. Bentonite clay, cobble, and cobble-gravel combinations reduce the rate of root and animal intrusion through experimental waste cover profiles compared to the sandy backfill. Intermediate scale studies with proposed barrier materials will provide further technical support for selecting effective biological intrusion barriers. Current data suggest that cobble-gravel combinations appear to offer the most resistance to biological intrusion when all factors are considered.

Important future goals of this study are to evaluate plant root effects on clay barrier integrity and to test cobble-gravel barrier systems at expanded scales. Experimental designs for the biological barrier studies will incorporate other factors affecting cover integrity as demonstrated by moisture and chemical cycling experiments and computer modeling.

ACKNOWLEDGEMENTS

This work was funded by the Department of Energy, Office of Nuclear Waste Management under contract W-7405-ENG36 with Los Alamos National Laboratory. We gratefully acknowledge the efforts of E. M. Karlen, J. L. Martinez, K. V. Bostick, B. J. Drennon, E. Lopez, W. Herrera, M. E. Montoya, E. F. Montoya, T. M. Jacques, E. Trujillo, M. Lewis, and L. J. Lane on this study.

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