WM'99 CONFERENCE, FEBRUARY 28 - MARCH 4, 1999

PERFORMANCE OF ALTERNATIVE ENGINEERED COVERS-- RESULTS OF 12 YEARS OF COVER PERFORMANCE IN LYSIMETERS AT A HUMID REGION SITE, BELTSVILLE, MARYLAND

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ABSTRACT

This project addresses a need for confirming methods of keeping water from waste. The concepts under investigation are applicable to near surface facilities as well as mined caverns. The project is significant in that it presents results of 12 years of actual cover performance at a humid region site. Long-term field projects on this scale are rare because of cost. Consequently, most reports on cover performance appearing in the literature are computer simulations. Of the concepts under investigation, two are particularly promising and are unique to this project. The first is a surface cover called *bioengineering*. Because it is a surface cover it is easy to maintain should there be subsidence. Bioengineering has the capability of (1) reducing infiltration of water through a cover to zero and (2) the remedial action capability of lowering the water table beneath a cover. The latter capability is a very important property for cleaning up sites in which there is water in disposal units. The second promising concept is called a *conductive layer barrier*. This is a special application of a capillary barrier, in which a capillary break is placed below a conductive layer. The conductive layer consists of material (e.g. fine sandy loam) which is capable of conducting water around waste under unsaturated flow conditions. In the absence of subsidence, such a system offers a significant margin of safety to cover performance particularly when it is placed below a geomembrane or a clay layer or a GCL, and it has a wide range of possible applications ranging from a tumulus to mined cavern disposal where there is intermittent fracture flow of water.

INTRODUCTION

This is a progress report of over 12 years of cover performance at a humid region site in Beltsville, Maryland. The project objective is to assess means for controlling water infiltration through covers of waste disposal units. Experimental work is being performed under natural conditions in large scale lysimeters (75' x 45 x 15') designed to collect a complete water balance. The lysimeters are instrumented to measure soil moisture in the cover layers as well as the soil beneath the cover. Data collection has been underway at Beltsville since 1987. Photographs and drawings of them can be found in U.S. Nuclear

Regulatory Commission report NUREG/CR-4918 Volume 10 by Schulz *et al.* 1997, and the report is available from the authors of this paper.

Three kinds of waste disposal unit covers or barriers to water infiltration are being investigated, and they are illustrated in Figure 1. They are: (1) *resistive layer barrier*, (2) *conductive layer barrier,* and (3) *bioengineering management.*

The concepts presented are applicable to LLW and HLW disposal, RCRA sites, uranium mill tailings, hazardous waste disposal, and sanitary landfills. The intended audience for this research is regulators as well as site operators. To date, two organizations are trying bioengineering covers in pilot programs. NYSERDA installed a bioengineering cover on a 550' X 35' LLW disposal trench at the West Valley, New York radioactive waste disposal facility, and in another pilot program, the U.S. Navy applied a bioengineering cover on 6 research plots on the east side of Oahu, Hawaii. Cost of the West Valley bioengineering cover was remarkably low. Design, materials, and installation cost was approximately $70,000 and maintenance is negligible.

DESCRIPTION OF BARRIERS AND RESULTS

(1) The Resistive Layer Barrier -- Figure 1 (a)

The *resistive layer barrier* functions by resisting water percolation. The resistive layer is commonly made of compacted clay but it could also consist of a geomembrane, a geotextile composite layer (GCL), or some combination of them. At Beltsville a locally derived clay is used as a resistive layer in three lysimeters. Because there is extensive experience on the performance of compacted clay barriers, the ones at Beltsville are primarily to provide comparative data. Two of the resistive layer covers have a fescue grass surface and one has an UMTRA cover of rip-rap. The UMTRA cover is more appropriate to an arid region and its installation at Beltsville is providing a severe test of a clay barrier.

Since compacted clays are a porous media subject to D'Arcy's Law[2] we expected to see water movement through them. To date, the performance of the clay barriers is better than expected in that the clay layers are acting as effective barriers to downward movement of water. It is only in the lysimeter covered with rip-rap that we see moisture levels increasing in the clay barrier (Figure 2). That is not unexpected as the rip-rap surface cover functions like a mulch.

One concern with clay barriers is the drying out of the clay during the summer which would lead to shrinkage and cracking. If this happens the clay layer would not be as efficient a barrier for preventing radon escape in UMTRA covers. Our experience at Beltsville is that in no case did the clay layer dry out significantly (|Figure 2). On the contrary the moisture level in the grass covered lysimeters is in a steady state condition. It is only in the lysimeter with the UMTRA cover that we see the moisture level rising suggesting some leakage of water through the clay layer would occur in the future. There was a slight leakage of water through the UMTRA cover in 1994-1995 (0.1 cm)[1] which may be associated with penetrations caused by the instrumentation. Minor remedial action was taken with the instrumentation and leakage has not occurred in succeeding years.

(2) The Conductive Layer Barrier -- Figure 1 (b)

The *conductive layer barrier* consists of two parts: (1) a conductive layer and (2) a capillary break. The conductive layer consists of a material (e.g. fine sandy loam) which is capable of conducting significant amounts of water around waste under a negative matric potential (i.e. unsaturated flow conditions) and it is placed over a capillary break. As long as moisture in the conductive layer is under tension the capillary break will be an effective barrier[3]. The importance of the *conductive layer barrier* system is that when it is placed below the *resistive layer barrier* it adds a considerable margin of safety to the cover because it will handle the leakage problems of *resistive layer barriers* if it is placed below them. In this position, the conductive layer barrier will -- (1) scavenge the small amounts of water that may leak through a resistive layer barrier because of construction defects, and (2) conduct the water around the waste. The theoretical basis for the *conductive layer barrier* along with a literature review are found in reference 4.

The material properties of the conductive layer are important because -- (1) a negative matric potential is needed to maintain a capillary break, and (2) the material should have the capability to conduct significant amounts of water under a negative matric potential. To identify appropriate materials for use in the field we did laboratory tests of the unsaturated flow properties of soils in beams with a 5:1 slope. (The soil beams and results are illustrated in reference 1). This kind of materials testing was unique to this project. We found a number of sands which provide acceptable flow rates of 10^{-3} to 10^{-4} cm/sec at a negative matric potential of -15 to -20 cm. Such material will be able to wick away the small amount of moisture passing through a *resistive layer barrier* and conduct it around waste.

At Beltsville, we placed a conductive layer barrier below a resistive layer barrier. Until seasonal 1993-1994 the cover was 100% effective in preventing water movement downward through the cover. In seasonal 1993-1994, 0.13 cm (0.05 in) of water passed through the cover. In seasonal 1994-1995, 0.21 cm (0.08) in of water passed through the cover. Although these amounts are an extremely small percentage of the total rainfall, in theory, no water should have percolated through the cover to the bottom of the lysimeter. It appears that this cover system was slightly compromised by the instrumentation installed to measure performance and we took measures to correct this. The corrective measures appear to be successful and no water passed through the cover in the following two years. To put this in perspective, the total leakage was only 0.34 cm (0.13 in) over a six year period. That is 0.34 cm (0.13 in) percolation out of a total rainfall of 665 cm (261 in).

(3) Bioengineering Management -- Figure 1 (c)

Multiple layer covers are vulnerable to subsidence. *Resistive layer barriers* and *conductive layer barriers* will fail it there is appreciable subsidence of the cover. Remedial action for multiple layer covers will be very difficult. A surface cover, called *bioengineering management*, is designed to overcome this problem. It consists of a surface cover of impermeable panels designed to promote run-off and limit infiltration. The impermeable panels are analogous to the roof of a house in which it is difficult and very expensive to make a leak-proof roof. If there are holes in the roof or cover, they will function like a one-way valve for water entry. Rather than trying to achieve a leak-proof cover an alternate approach is used. Drought resistant vegetation is planted in narrow rows between the surface panels. Their purpose is to remove the small amount of leakage that gets through the panels. At Beltsville, 92% of the surface is covered with impermeable panels to limit infiltration, a 5:1 slope is used to enhance run-off, and a drought resistant species of juniper (Pfitzer juniper) is planted in 4" openings between panels to remove moisture from the soil.

The first application of bioengineering was in 5' diameter circular lysimeters constructed at the Maxey Flats LLW disposal facility. The lysimeters had an existing crop of Kentucky red fescue grass. For this first attempt we used a 70% cover. After two successful years in which there was no deep percolation in the lysimeters with a bioengineering cover the fescue grass was replaced with Pfitzer juniper. There was no deep percolation during the two succeeding years in which the lysimeters were in operation. At the same time, there was significant deep percolation through adjoining lysimeters that had only fescue grass with no enhanced run-off. Because of these encouraging results we scaled up the covers at Beltsville and increased the coverage from 70% to 92%. The performance data for Maxey Flats are found in reference 5.

Performance of the two Beltsville lysimeters with a *bioengineering* cover is a complete success. The lysimeters are filled with soil and simulated 55 gallon waste drums are on the bottom of the lysimeters. To demonstrate what would happen with a flooded disposal unit, data collection began with a water table 2 meters above the bottom of one lysimeter and 1 meter above the bottom of another lysimeter. The juniper plants functioned as a pump; and they removed the water from the two lysimeters in which they are placed. There has been no measurable water at the bottom of either lysimeter since 1989 and this is shown in Figure 3 (a).

Soil moisture was measured by a neutron probe calibrated to the site=s soil. From 1986 to 1998 soil moisture has dropped from saturation until it is beyond the permanent wilting point of agricultural crops. The soil moisture data may be seen in Figure 3 (b). The system is continuing to perform well and the juniper are surviving nicely although the soil moisture is exceedingly low (less than 5% moisture by weight). A photograph of the juniper is found in reference 1.

APPLICATION

A *bioengineering* management cover would be very effective at sites subject to subsidence. During the subsidence period some minor maintenance would be necessary. This would represent a low cost management of the site. Following cessation of subsidence, a final cover could be installed. If a clay barrier is used to limit water infiltration, the cover will be "sensitive" to imperfect construction or degradation by penetrating roots. The roots will die and decay, causing markedly increased permeability of the clay with the passage of time. However, if a *conductive layer* is placed under the clay layer to scavenge water, the system will be "robust". Roots will still degrade the clay layer, but will not degrade the conductive layer (*i.e*. the scavenging layer) because a root hole through it will be analogous to a hole through a wick. The hole will do no significant damage. The combination of a *resistive layer* with a *conductive* (scavenging) layer underneath is (1) tolerant of construction defects, and (2) resistant to damage by root invasion. If stable geological materials are used and in the absence of subsidence such a system will function effectively for millennia.

The *resistive layer barrier/conductive layer barrier* system has a wide range of application from above grade disposal (e.g. a tumulus) to mined caverns in which there is intermittent fracture flow of ground water. It is particularly useful for protection of earth mounded concrete structures (Figure 4 (b). In that case, the barrier system would shield the concrete from exposure to flowing water. The resulting stagnant film of alkaline water on the surface of the concrete would protect it from degradation over a long time period. This system could also be for mined cavern disposal, and it would enhance the margin of safety by being able to conduct fracture flow water around the waste (Figure 4 (a).

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contribution of Dr. Robert K. Schulz, of the University of California Berkeley who conceived the concepts of the conductive layer barrier and bioengineering. He directed the research at Maxey Flats and at Beltsville.

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Fig. 1 Cover types

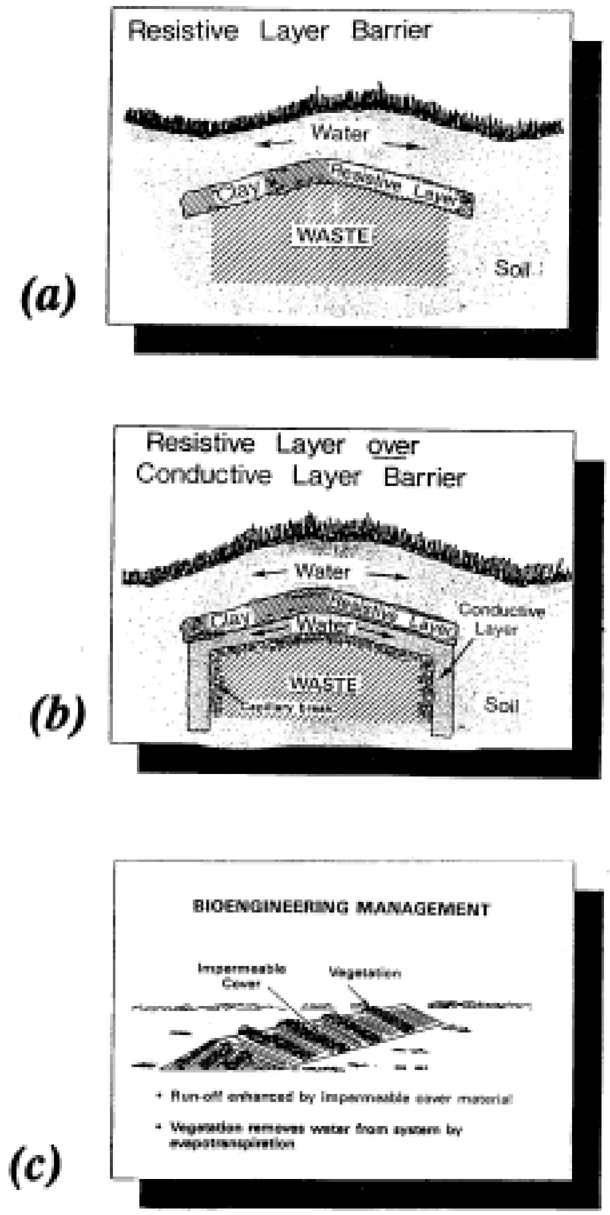


Fig. 2 Soil moisture in resistive layer

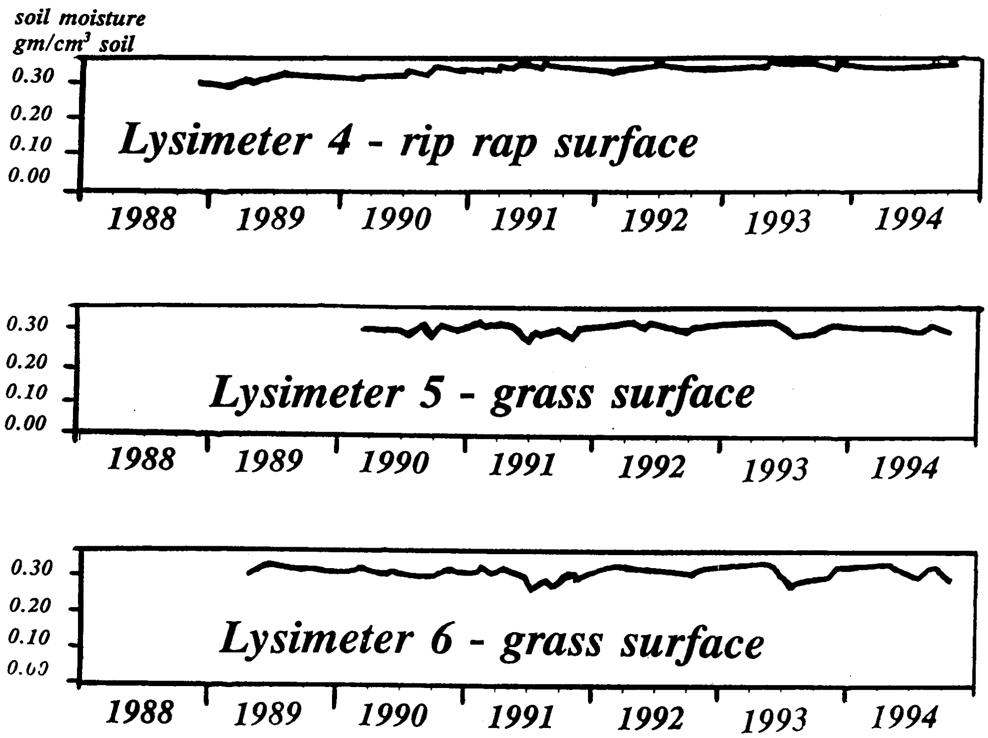
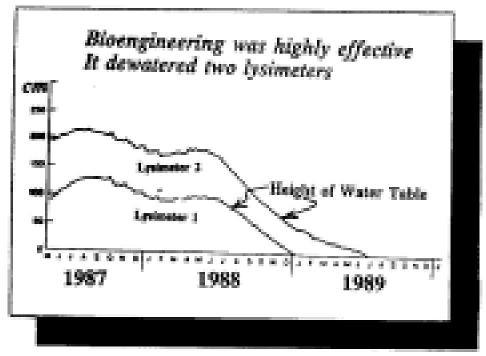
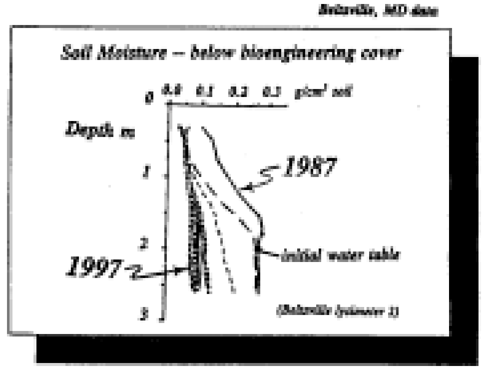


Fig. 3 Results -- bioengineering



(a)



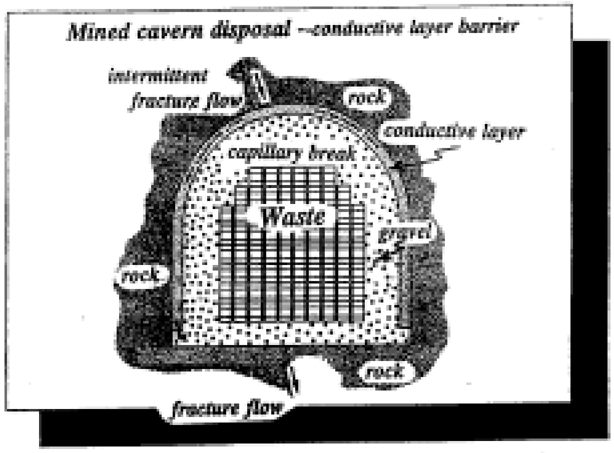
(b)

Bioengineering -- where applied

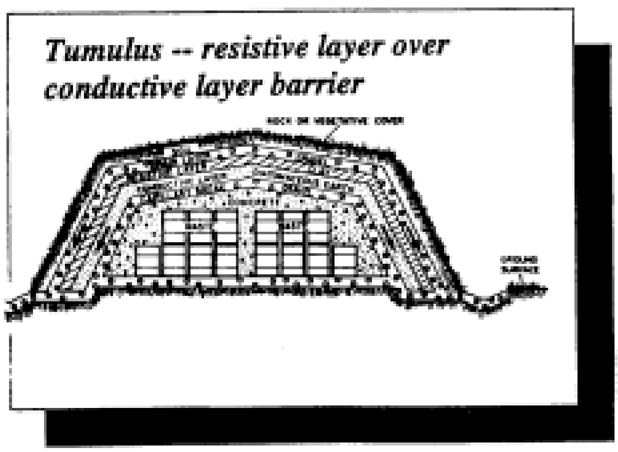
site	*% cover*	*period*	*vegetation*
Maxey Flats, Ky	*70%*	*1984-1988*	*fescue grass*
Beltsville, Md	*92*	*1986-present*	*Pfitzer's juniper*
West Valley, NY	*92*	*1993-present*	*Pfitzer's juniper*
Oahu, Hawaii	*40*	*1995-1998*	*native vegetation*
	25	" "	" "

(c)

Fig. 4 Conductive layer barrier -- application



(a)



(b)