NOVEL EXPERIMENTS FOR UNDERSTANDING THE SHALLOW-LAND BURIAL OF LOW-LEVEL RADIOACTIVE WASTES

by

G. L. DePoorter, W. V. Abele, T. E. Hakanson,
B. W. Burton, and B. A. Perkins

Environmental Science Group
Group LS 6, MS-K495
Los Alamos National Laboratory
P. O. Box 1663
Los Alamos, MN 87545

ABSTRACT

Three field experiments that will provide data on water movement in SLB facilities are described. The experiments are designed to measure water movement, to quantify techniques to control water movement, and to determine the effects of surface moisture content fluctuations on liquid and vapor movement back to the surface.

INTRODUCTION

Experiments to provide data on the basic processes that occur in the shallow land burial of low-level radioactive wastes are necessary to engineer facilities with guaranteed performance, to validate models for system predictions, and to provide input to models that consider contaminant pathways out of the facility. Experimental results from appropriately sized field experiments are not now available. Three types of novel experiments are providing experimental data on the basic processes of water movement in shallow land burial facilities. The field facility in which the experiments will be performed will also be described briefly.

EXPERIMENTAL FACILITY

These experiments will be performed in the Los Alamos Experimental Engineered Test Facility, which has been described in detail

elsewhere.^{1,2} Briefly, this is a 21 acre facility, located in Los Alamos, N.M., dedicated solely for experiments on low-level radioactive waste management. An Experiment Cluster, a unique feature of this facility, is shown in plan and section views in Figure 1. Each Experiment Cluster provides six caissons, three meters in diameter and six meters deep, for experiments under controlled and measurable hydrologic conditions. In addition, in each Experiment Cluster there are five caissons, about one-half meter in diameter and six meters deep. In the instrument and access caisson, ports at regular intervals can be used for instrument emplacement or sampling of the experiments in any of the eleven experimental units. Two experiment clusters are currently emplaced in the Experimental Engineered Test Facility.

DESCRIPTION OF EXPERIMENTS

Water is an important component in the performance of a shallow land burial waste disposal facility. Therefore, generic experiments have been designed to understand the movement of water and how to move water in a controlled manner. The Moisture Cycling Experiment is designed to study the movement of water in vapor and liquid phases in response to changing surface moisture conditions.

Water Movement Experiment

The Water Movement Experiment is designed to measure the unsaturated hydraulic conductivity of a typical backfill material as a

FIGURE 1. Experiment Clusters

function of water content on a scale typical of that in an actual shallow land burial facility. Therefore, these experiments will be performed in two of the large caissons in the Experiment Clusters and the backfill material will be crushed Bandalier Tuff. The unsaturated hydraulic conductivity will be measured by the instantaneous profile method described by Watson.¹ The application of this method and the calculational techniques are described in further detail by Hillel and co-workers² and by Hillel.³

In the instantaneous profile method, the matric potential of the soil is measured as a function of time and depth in a soil profile by means of tensiometers. The unsaturated hydraulic conductivity is measured as the same function of time and depth in the soil profile by means of a neutron moisture probe. From these data, the unsaturated hydraulic conductivity can be calculated as a function of water content. The procedure recommended by Hillel³ will be used in our experiments. Tensiometers will be placed in the soil profile each 0.38 m. Water will then be ponded on the surface until the entire profile becomes as nearly saturated as possible. The soil surface will then be covered to prevent any further water flux into the soil column from rainfall or out of the column by evaporation. As the column drains, measurements of matric potential and water content will be made.

The experimental configuration and instrument emplacement is shown in Figure 2. In addition to the horizontal neutron moisture probe access tubes, which extend 1.5 m into the soil column, there is also one vertical neutron probe access tube. These tubes are aluminum, with a 50.8 mm outside diameter. The thermocouples are copper-constantan and have all been calibrated at the ice point and at the boiling point of water at Los Alamos elevation, approximately 93°C. The two large thermocouple harnesses are emplaced to determine the temperature variation across the soil column at two elevations. The other thermocouples are to determine the temperature as a function of depth in the column. The thermocouple harnesses were emplaced during the

filling operation. All other instruments were emplaced after the units were backfilled and compacted. Two caissons were filled for this experiment.

The filling and compacting procedures and the emplacement technique for the neutron moisture probe access tubes is described elsewhere.⁴ The tensiometers are currently being emplaced. When the emplacement is completed, the experiment, as described above, will be started. Some initial observations, however, are in order. As illustrated in Figure 2, there is a drain in the bottom of each unit. During filling, the moisture content of the crushed Bandalier Tuff varied from 10 to 15 percent, far from saturation. Immediately after filling, water started draining out of each column, as evidenced by a constant dripping from each unit in the drain line located in the instrument and access caisson. Routine measurements of water have been made since the units were filled.

Saturation of the columns should take approximately three months and the drainage will proceed for over a year. Data will be collected over this entire time period from which unsaturated hydraulic conductivity can be obtained as a function of water content. These data can be used to determine the need for other system components, such as migration barriers, and can be used to determine the performance requirements of these components.

Water Control Experiment

Small scale modeling has demonstrated that it is possible to maintain dry structures in porous media by using capillary barriers. These barriers are created by differences in particle size distribution and do not depend on the nature of the separation interface. This phenomenon is due to the predominance of capillary suction over gravity forces. The percolating liquid will penetrate the coarser material

FIGURE 2. Experimental Configuration

only after the overlying finer one is totally humidified. Consequently, the structure is maintained dry, even under a permanent regime of non-saturating infiltration. As long as the pressure at the coarse-fine interface remains negative, water infiltrating into the finer layer will not cross the interface but will flow laterally within the finer layer until local percolation reoccurs upon reaching the edge of the coarser material. The limiting granulometric differences beyond which this phenomenon ceases to exist have been determined. Corey and Horton³ referred to it as the "wick effect." They found that, under unsaturated conditions, a gravel lens caused lateral flow in a finer-textured overlying material. The lateral distance over which the water can be transported is limited and is also a function of the slope of the system.

At a particular matric potential, all pores which are sufficiently small to exert a capillary suction equal to or greater than the matric potential will be filled with water. Consequently, a fine-grained material will contain more water than a coarse-grained one at equal matric potentials. During drainage, an initially saturated soil will drain its largest pores first, while in wetting a dry soil, the smallest pores will fill first and as the matric potential is allowed to increase (become less negative), the water content increases as progressively larger pores are filled. This will be accompanied by an increase in hydraulic conductivity that would tend to increase horizontal diversion of water already promoted by the presence of a sloping interface. The coarser medium, on the other hand, with its predominantly large pores, will remain dry with a low hydraulic conductivity until the matric potential reaches zero at the interface. The system will fail when the matric potential at the interface becomes non-negative. In the experiments described here, point readings of the matric potential at the interface will be made using tensiometers.

In practical applications of wick systems, the interpenetration of the finer material into the coarser material can affect the system performance. This interpenetration of the finer materials into the pores of the coarser one can be prevented by using a polypropylene mat or fabric. It cannot be overemphasized that the efficiency of the capillary screen is in direct proportion to the abruptness of the material transition at the interface.

The extent to which a negative matric potential can be maintained at the interface depends on several factors, some of which deserve closer attention. They are:

- (1) Degree of contrast in matric potential water content curves of the fine and coarse materials.
- (2) Hydraulic conductivity of the fine material
- (3) Thickness of the fine layer as a function of specific amounts of percolating water.
- (4) Length of the interface
- (5) Slope of the interface

Factors 1, 2, and 3 with a constant slope of 24% are being investigated in experiments currently in place in the Los Alamos Experimental Engineered Test Facility. These experiments are emplaced in corrugated metal culverts 3 m in diameter and approximately 1 m high placed on top of the ground on a layer of gravel to divert the water away from the experiment. In each experiment the coarse material is gravel, while sand is the fine material in one experiment and crushed Bendolite Tuff is the fine material in the other. Otherwise, the experimental are identical. In each experiment interpenetration of the finer material into the pores of the coarser one is prevented by using Mirafi's 600X Embankment Stabilization Polypropylene Fabric. By using sand and crushed tuff for the fine materials factors 1 and 2 above will be investigated.

Tensiometers are located at the interface between the fine and coarse materials. Taking the wick base as the reference plane, the tensiometers are at an elevation of 0 m, 0.094 m, 0.188 m, and 0.281 m, respectively. The upper tensiometer is at a level 0.12 m below the wick-air interface (ground level). The influence of the thickness of the wick, factor 3, will be investigated by gradually augmenting its thickness and measuring the position of the failure spot as a function of specific amounts of percolating water. Factor 4, length of the wick, will be investigated in larger experiments than is possible in these culverts. Factor 5, slope, will be investigated by removing the experiments from the above ground culverts and rebuilding them with a different slope. Figure 3 illustrates a conceptual wick system experiment.

The figure shows the locations of the tensiometers and the neutron moisture probe access tubes. In the experiments emplaced in the field only one slope is used and the tensiometers are not in line as shown in the figure. These experiments are in progress and will provide the information from which effective designs can be made for constructing water diverting covers for low-level radioactive waste disposal trenches.

Moisture Cycling Experiment

This experiment was initially designed to provide information on a phenomenon which occurs in arid or semi arid environments. During the hot, dry spring and summer months the surface of a low-level waste disposal facilities dries out. If a significant rainfall event occurs, such as a severe summer thunderstorm, which may deposit up to 50 mm precipitation at one time, the surface of the burial trench will become

FIGURE 3 Conceptual Design for Wick Experiment

wet and part of the water will infiltrate into the burial pit. After the storm is over, the surface will dry out, providing a driving force to bring the infiltrated water back to the surface. The concern with this phenomenon is that when this infiltrated water comes back to the surface of the facility radioactive contaminants may be brought along with this water.

The important variables identified for this experiment are (1) average initial water content of the backfill material, (2) depth beneath the surface of the contaminants that could be transported back to the surface, (3) the presence or absence of plants on the surface which will affect the water balance in the profile, and (4) whether contaminants are transported in the liquid or the vapor phase.

The experiment is being performed in 153 experimental metal culverts 0.60m in diameter and 1.5 m deep with a welded, but not sealed steel bottom. These units were placed in an evacuated trench and backfilled to within a few centimeters of the top. An aluminum neutron moisture probe access tube is placed in the center of each unit and copper-constantan thermocouples are placed, starting at the surface, with successive spacings of 1, 2, 4, 8, 16, 32, and 64 cm with one additional thermocouple at the bottom of the unit. These experimental units are illustrated in Figure 4.

The tracers used in this experiment are stable cesium, strontium, and cobalt to follow the liquid phase movement of contaminants and tritium as tritiated water to follow the movement of contaminants in both the liquid and vapor phases. As indicated in Figure 4, the top of the tracer layer was either 30 or 60 cm from the surface of the experiment. Experiments were emplaced with either about 10 or 20 volume % water and the backfill material was crushed Bandelier Tuff.

For each moisture content there are eight experimental units, four with plants and four without plants. In each of these four, two units have the tracer layer at 30 cm and two units have the tracer layer at 60 cm. Regular measurements are being made of the temperature and moisture content in each of these units. During the summer of 1982, these experimental units will be removed intact, and horizontal samples taken at several depths in the profile. These samples will be analyzed for cesium, strontium, cobalt, and tritium. The data will then be analyzed to determine the extent of upward contaminant transport due to moisture cycling.

Although this experiment was initially designed to provide data on the problem described above, it is also providing extensive experimental data on another important process that occurs in SLB facilities. This process is the effect of plants on the water balance in the soil profile. All

FIGURE 4. Moisture Cycling Experimental Unit

COMPONENTS OF THE MONTHLY WATER BALANCE
FOR BARE SOIL AND VEGETATED PLOTS IN THE
MOISTURE CYCLING EXPERIMENT

FIGURE 5. Average Soil Moisture Content in Moisture Cycling Experimental Units 1A and 1B

16 experimental units were subjected to the same amount of added water and precipitation. Figure 5 is a plot of average soil moisture content in experimental units 1A and 1B from July to December of 1981. Unit 1A has no plants and unit 1B has plants; both units were emplaced with the same moisture content, about 10 volume %. The plants were started in early July. As is seen from Figure 5, once the plant cover became established in August, the average moisture content of the experimental unit with plants became less than the average moisture content in the experimental unit without plants.

The plants are removing water from the soil profile by transpiration. Other measurements from this experiment indicate that once water infiltrates beneath a given depth, which is different for bare and vegetated soils, the water does not come back to the surface. Therefore, the plants can prevent water from getting into the burial pit. If there were no plant cover, this water would infiltrate into the buried wastes. Extensive data analysis is now in progress for this experiment. When completed, it will be published elsewhere.

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