Biobarriers Used in Shallow-Burial Ground Stabilization

J. F. Cline

March 1979

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Richland, Washington 99352

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INTRODUCTION

Shallow earth burial has been a successful technique for safe storage of low-level radioactive dry wastes since the establishment of the Hanford Site in 1943. The primary technique employed involves digging a trench, putting wastes on the bottom of the trench, and covering them with backfill earth. Since many of the natural soil profiles in the 200 Areas of the Hanford Reservation consist of cobble overlain by topsoil, the backfill material often consists of a heterogeneous mixture of soil and cobble. Revegetation of these burial sites has been allowed to occur naturally. Most surfaces in the 200 Areas have developed irregular stands of the shallow-rooted cheatgrass (Bromus tectorum L.), along with deeper-rooted species such as the Russian thistle (Salsola kali L.) and gray rabbitbrush (Chrysothamnus nauseosus (Pall.) Britt.).

In almost all instances, buried wastes have remained successfully removed from biological accessibility. Occasionally, however, deep-rooted plants or burrowing animals have brought radioactive material to the surface where it can enter ecological food chains and undergo biological magnification. Most reports of biological interaction with buried radioactive wastes have involved plants. Russian thistle accumulated ^{90}Sr in its shoots when roots were in contact with soil containing radio-strontium (Selders 1950). Russian thistle also accumulated transuranic elements in its tissues at higher levels than does cheatgrass grown under the same environmental conditions (Schreckhise and Cline 1979). In addition, gray rabbitbrush plants growing on soil backfill over a 200 Area crib were reported to accumulate fission products (Klepper et al. 1978). These reports indicate the need for an economical, effective method of preventing plant roots from invading buried wastes.

Burrowing animals have also reached buried wastes. Radioactive salts (mostly ^{90}Sr and ^{137}Cs) were exposed by a deep-burrowing animal, perhaps a badger (O'Farrell and Gilbert 1975). The exposed salts were directly ingested by black-tailed hares, which spread ^{90}Sr and ^{137}Cs in a crib area in fecal pellets and urine. After an asphalt coating was put down to reseal the source of salts, fecal pellets of black-tailed hares were collected from the crib area and sorted according to age. Test results showed that the asphalt pad probably

sealed the source of contamination. This incident also indicated the need to develop biobarriers to prevent animals from burrowing into buried wastes.

Stabilization of a shallow burial site requires some means of keeping buried radioactive wastes in place and preventing the movement of radioactive elements into the biosphere by various vectors present in the soil covering the burial site. By placing a barrier between the surface of the soil and the buried wastes, it would be possible to isolate the wastes from the biosphere and eliminate the movement of radioactive elements into the environment. An effective biobarrier would make it possible to grow plants over the buried wastes regardless of rooting habits; the plants would stabilize the surface soil, prevent wind erosion, and transpire soil water back into the air, thus preventing it from percolating downward through the buried wastes.

This report summarizes the finding of a study undertaken to determine the effectiveness of natural cobblestones as a long-term biobarrier. In the initial field study, we investigated whether a thick layer of cobblestones would prevent plant roots and burrowing animals from reaching contaminated materials and transferring radionuclides to the soil surface. In a subsequent greenhouse study, three modifications of the cobblestone barrier were tested, including the addition of another layer of stones, one of asphalt, and one of a root toxin.

METHODS

In 1975, an abandoned ditch just outside the south boundary fence of the 200 West Area (Figure 1) was chosen as the site of the cobblestone biobarrier study. The area was selected because of its proximity to other similar studies in progress and because the excavation needed to install the barrier was already provided by the ditch. The area was uncontaminated and was situated outside a radiation zone, making sampling and maintenance simple and inexpensive. The topography, soil type, and climatology of this location are similar to those of waste burial sites on the 200 Area plateau (Cline et al. 1975).

CONSTRUCTION AND SPECIFICATIONS OF TRENCH PLOT

The construction of the trench plot (Figure 2) began with the placement of moisture probe wells. These wells were made of electrical conduit 3.8 cm

FIGURE 1. Location of Biobarrier Demonstration Site

FIGURE 2. Sectional View of Trench Plot

in diameter and 3.05 m in length, with the bottom capped. Five wells, extending to a depth of 2.9 m, were placed along the center-line of the trench, spaced evenly at 15.24 m from each other (Cline and Holter 1977).

A lithium chloride tracer was added to the plot, mixed in a strip 1.22 m wide by 0.15 m deep. The strip extended along the center of the trench for a length of 61 m and at a depth of 2.4 m from grade level. The concentration of the mixture was 50 ppm lithium with soil by weight.

A back-up tracer system also used in the trench plot consisted of two perforated pipes placed parallel to and 0.15 m on either side of the center-line of the trench. Each pipe consisted of three parts: a horizontal center section fitted with drip irrigation emitters, and two vertical end sections

without emitters. The horizontal section was placed at a depth of 2.4 m and ran the length of the trench. The vertical sections were used to introduce chemicals from grade level to the horizontal section. The entire system was fabricated from plastic pipe with an inside diameter of 0.95 cm.

Next, 0.15 m of topsoil was added to the whole trench, followed by a 1.2-m-deep layer of cobblestones with diameters measuring 3.8 to 7.6 cm. The top of the rock layer measured 6.1 m wide by 61 m long, with the sides sloping inward with the angle of the trench (Figure 2). Care was taken to prevent damage to the moisture probe wells during the addition of the cobble. The rock layer was then covered with 0.9 m of topsoil and a small quantity of bentonite clay was mixed with the surface 0.15 m of soil.

The area was seeded to cheatgrass using a seed spreader, then fertilized with NH_4NO_3 at the rate of 67 kg of available nitrogen per hectare. The area was packed and then watered using a tank truck.

TEST SPECIES USED AND ANALYSES PERFORMED

A small mammal-proof fence was built around the area (Figure 3). In June 1977, five pocket mice (two males and three females) were placed in the enclosure and fed bird seed initially until they became acclimated. During that summer, the animals were trapped periodically in live traps, and feces and hair were collected from each animal and tested for lithium; significant quantities of lithium would indicate that the animal had burrowed through the barrier and become contaminated with the lithium below.

At the same time, three colonies of harvester ants were dug up from the surrounding area and placed in three 1.4-m^2 circles located throughout the enclosure. Each circle was surrounded by 7.6-cm-high aluminum edging (Figure 3). The ants were fed seeds during the first weeks so they could establish themselves and locate food. In a short time they dug into the soil and made tunnels for their queen and workers. (A typical harvester ant tunnel is shown in Figure 4.) Sampling involved collecting ant carcasses and excavated soil around the tunnels and analyzing them for lithium content to identify whether the ants had burrowed through the cobblestone barrier into the lithium tag below.

FIGURE 3. Mammal and Ant Enclosures on Biobarrier Site

After the initial seeding with cheatgrass, the area was left to reseed itself naturally to three annual plants, cheatgrass, Russian thistle, and mustard (*Sisymbrium altissimum* L.). The plants were harvested about three times during the growing season. Aboveground plant parts were clipped, placed in plastic bags, and taken to the United States Testing Company to be chemically analyzed for lithium. The analyses were performed to determine whether the roots had penetrated the cobblestone barrier, reached the simulated buried waste, and translocated it to the aboveground plant parts.

FIGURE 4. Harvester Ant Tunnel

BARRIER MODIFICATIONS USING LYSIMETERS

To test several modifications in the design of the cobblestone barriers, 16 lysimeters were constructed: four controls, and four each with three different layer types placed over the cobblestone. The lysimeters were constructed of polyvinyl chloride pipe 12.7 cm in diameter. Each one contained 2.54 cm of soil mixed with a lithium chloride tracer, with a 60-cm layer of washed cobble (2.54 to 5.1 cm in diameter) over the soil and tracer Figure 5). In the control lysimeters, dry sandy topsoil was poured directly over the cobble; the

FIGURE 5. Barrier Modifications Tested in Lysimeters

layering of material in these lysimeters, then, was identical to that in the trench plot except that the depth of each component was less. The barrier modifications in the remaining 12 lysimeters consisted of:

- a 25-mm layer of small stones (0.3 to 0.6 cm in diameter) placed over the cobble, with topsoil over the stones;
- a 25-mm layer of small stones, with 175 cc of 10% asphalt emulsion in water poured over the stones before the topsoil was added;
- a 25-mm layer of small stones, with asphalt emulsion mixed with root toxin poured over the stones before the topsoil was added. The root toxin was made up of 66.5% $\text{Na}_2\text{B}_2\text{O}_4 \cdot 4\text{H}_2\text{O}$ and B_2O_3 ; 30% NaClO_3 ; 1.5% Bromacil; and 2.0% inert material.

The lysimeters were placed in a greenhouse, watered, and planted to cheatgrass. The cheatgrass was harvested and analyzed for lithium to determine whether the roots had passed through the barrier into the lithium-tracered soil at the bottom of the lysimeters. After the cheatgrass was harvested, Russian thistle was planted in the lysimeters. The plants were grown to a height of 30 cm, harvested, and analyzed for lithium.

Following the harvest, the lysimeters were taken to the laboratory, the soil was wetted to full capacity, and the walls of the lysimeters were split lengthwise with two cuts down opposite sides (Figure 6). The halves of each lysimeter were laid open, the roots in the soil and cobble profile were observed, and pictures were taken of each lysimeter as a record of root configurations.

FIGURE 6. Control Lysimeter Split in Halves

RESULTS AND DISCUSSION

Table 1 shows that three Russian thistle plants in the trench plot produced roots that grew through the topsoil and cobblestone layers and into the buried LiCl tracer 2.4 m below the soil surface. The root system transported the lithium to the aboveground plant parts. At this time we do not know why or how some roots passed through the cobblestones to the lithium while others did not, but it is possible that very sandy topsoil sifted into the cobble, making a path that the roots followed to the buried lithium. This process was seen in the small lysimeters in the green-house study. The two plants that penetrated the barrier in 1978 were marked so that the roots could be followed by removal of the soil and cobble around these plants.

No animal or ant penetrations into the buried lithium were observed during 1977 or 1978. This indicates that cobblestone is an effective barrier that prevents burrowing animals and insects from entering a buried substance.

TABLE 1. Penetrations of the Cobblestone Barrier
at the 200 West Trench

	<u>Number of Penetrations (n)*</u>		
	<u>1976</u>	<u>1977</u>	<u>1978</u>
<u>Plants</u>			
Cheatgrass	0 (24)	0 (10)	0 (10)
Mustard			0 (4)
Russian Thistle	1 (47)	0 (45)	2 (25)
<u>Ants</u>			
Carcass		0 (6)	0 (18)
Excavated Soil		0 (9)	0 (19)
<u>Mice</u>		0 (14)	0 (5)

* (n) number of samples analyzed.

The use of the small stones alone and in combination with asphalt and the asphalt-root toxin considerably improved the effectiveness of the cobblestone barrier, as shown in Table 2. In the control lysimeters which had the same barrier layers as the trench plot, the topsoil sifted into the cobblestone layer (Figure 6) and the roots of the Russian thistle passed through the cobble and into the lithium layer at the bottom of the lysimeters. The cobblestones and the entire length of the lysimeters were wet, indicating that the moisture from the wetted soil passed through the soil to the layers below.

In the lysimeters that had a thin layer of small stones over the cobblestones, the topsoil remained in place and did not sift into the cobblestone (Figure 7). Plant roots passed through the layer of small stones, but the roots in only two of the lysimeters had reach the buried lithium when the aboveground parts of the Russian thistle were analyzed. While it is probable that over a longer growing period all the roots in these lysimeters would grow

TABLE 2 . Percent Effectiveness of the Various Layering Treatments in Preventing Roots from Penetrating the Barrier

	<u>Control Topsoil Over Cobble</u>	<u>Small Stones Between Topsoil and Cobble</u>	<u>Asphalt and Small Stones Between Topsoil and Cobble</u>	<u>Asphalt-Root Toxin and Small Stones Between Topsoil and Cobble</u>
Topsoil Sifted into Cobble	0	100	100	100
Roots Passed Barrier into Cobble	0	0	100	100
Excess Water in Cobble	0	0	100	100
Roots Passed Barrier to LiCl Layer	0	50	100	100

FIGURE 7. Lysimeter with Small Stone Barrier

into the lithium layer, the rate of root penetration was slower than in the controls, indicating that air spaces between the stones may slow root growth. Possibly stones larger than the 0.3- to 0.6-cm stones used in the experiment would be still more effective in reducing root penetration.

An asphalt layer, formed by pouring an emulsion over a layer of small stones, was 100% effective in preventing topsoil from sifting into the cobble and roots from passing into and through the cobble to the lithium layer (Figure 8). In these lysimeters the cobblestones were nearly dry, probably because of the water-tight seal made by the asphalt emulsion layer. A water-tight barrier may thus help prevent root penetration, since roots do not generally enter very dry zones.

When a root toxin was mixed with the liquid asphalt emulsion and poured over a thin layer of small stones, plants died when their roots came into contact with the toxin (Figure 9). This barrier modification was 100% effective in all categories measured and could be used over waste storage areas if one did not need vegetative growth on the soil surface. Where surface growth is needed, placing the root toxin below the cobblestones might prevent the roots of deep-rooted plants from entering the waste without poisoning shallow-rooted plants such as cheatgrass.

FIGURE 8. Lysimeter with
Asphalt and Stone Barrier

FIGURE 9. Lysimeter with
Asphalt, Root Toxin, and
Stone Barrier

CONCLUSIONS

These data show that cobblestone can be effective as a barrier to burrowing animals and insects, but not totally effective as a barrier to plant roots.

Because of variable weather patterns at Hanford, five to six year studies are recommended for further evaluation of the effectiveness of different materials as biobarriers to radioactive substances.

The following criteria must be met to prevent plant roots from entering buried waste and transporting radioactive or other elements to the soil surface where they can enter the food web:

- the burial zone beneath the cover should be kept dry.
- enough soil or other water-retaining substance should be placed in the cover to hold annual precipitation.
- plants or other substances should be placed in the cover to remove soil moisture from site each year via evaporation and plant transpiration.
- different additions to the cover should be designed and placed over the buried waste to prevent burrowing animals from causing channelization of water through the cover to the lower levels.

Stone size appeared to affect the plants' rate of root growth since root growth slowed in the air spaces between stones. Root toxin was 100% effective as a means of keeping roots out of the buried waste; this method could be used as a barrier modification where no plant cover is needed.

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