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Experimental Design for Demonstration of Bio-barriers Placed in a Simulated Burial Trench

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EXPERIMENTAL DESIGN FOR DEMONSTRATION OF BIO-BARRIERS PLACED IN A SIMULATED BURIAL TRENCH

by

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May 1976

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SUMMARY

This report describes studies which have been undertaken to improve burial techniques to prevent the intrusion of buried wastes by plants and animals. The study consists of two parts. The first part is a demonstration trench in which a layer of cobble has been placed over simulated wastes and covered with a deep layer of topsoil. The second part is an experiment in which several different kinds of biological barriers are tested in a replicated plot design. The "simulated wastes" consist of soil mixed with lithium chloride, which is biologically available and can be easily detected by spectrophotometric analysis. The purpose of the study is to evaluate the effectiveness of these barriers to biological invasion of buried wastes.

INTRODUCTION

Earth burial has been a successful technique for safe storage of low-level radioactive dry wastes since establishment of the Hanford Reservation in 1943. The primary technique employed involves digging a trench, putting wastes on the bottom of the trench, and covering with backfill earth. Since many of the natural soil profiles in the 200 areas have 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 have developed irregular stands of the shallow-rooted grass, cheatgrass (*Bromus tectorum*), along with deeper-rooted species such as Russian thistle or tumbleweed (*Salsola kali*) and gray rabbitbrush (*Chrysothamnus nauseosus*).

Buried wastes have remained, in almost all instances, successfully removed from biological accessibility. However, there have been a few instances where deep-rooted plants or burrowing or digging animals have brought radioactive materials to the surface where they could enter ecological food chains. Most of the reports of biological interaction with waste have involved plants. For example, Dabrowski (1973) analyzed tumbleweeds on burial grounds in the 100 areas and found ^{137}Cs, ^{65}Zn, and ^{60}Co in their shoot tissues. Selders (1950) found that Russian thistle accumulated ^{90}Sr in shoots when roots were in contact with soil containing radiostrontium. Price (1972) showed that Russian thistle and bursage (*Ambrosia acanthicarpa*) accumulated transuranic elements in their tissues at higher levels than did cheatgrass grown under the same environmental conditions. In addition, gray rabbitbrush growing on the 216-A-24 crib has been reported to accumulate fission products, especially ^{137}Cs (Klepper et al., 1975). Thus, it would be useful to find an economical method whereby the invasion of buried wastes by plant roots could be prevented.

Digging and burrowing animals also have the potential for penetrating buried wastes. Radioactive salts (mostly ^{90}Sr and ^{137}Cs) were exposed by a deep burrowing animal, probably a badger (Taxidea taxus). The exposed salts were directly ingested by black-tailed hares (Lepus californicus). The hares spread ^{90}Sr and ^{137}Cs in the B-C crib area in fecal pellets and urine (O'Farrell and Gilbert, 1975). An asphalt coating was put down to reseal the source of salts. Fecal pellets of black-tailed hares were later collected from the B-C Crib area and sorted according to age. Detectable levels of radioactivity were found only in the older pellets, indicating that this asphalt pad probably sealed the source of contamination (Uresk et al., 1975). This incident indicated the need for the development of bio-barriers which would effectively prevent these animals from burrowing into buried wastes.

SITE DESCRIPTION

The area chosen for the experiment, designated as the bio-barrier demonstration site (Figure 1), consisted of a large trench with a smaller side ditch. The soil that was removed from the original excavation was heaped alongside the trenches. The larger trench was chosen as the site for the large experimental plot and the smaller ditch was used for the site

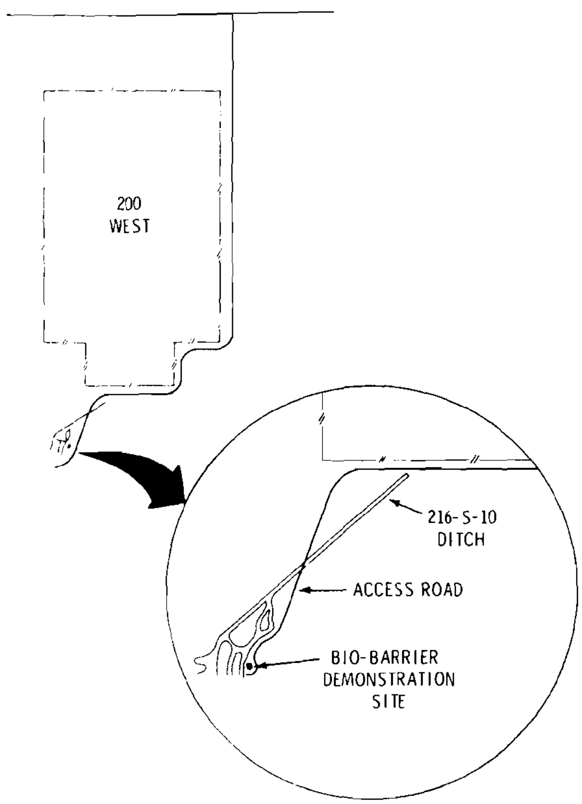

FIGURE 1. Location of Bio-Barrier Demonstration Site in the 200-W Area

of the multiple plot experiment using partly buried circular concrete containers. The original vegetative cover was removed approximately 25 years ago during the construction of the REDOX plant. Since abandonment, the area has been recolonized with cheatgrass and other annuals. The topography is nearly level, so environmental factors such as wind, sun exposure, and rainfall will be about equal in all segments of the experimental area. The original excavation spoils were leveled during construction of the plots to remove any topographic variables. The site is situated outside the 200 West area perimeter fence and near other experimental plots, making the plots easily accessible for sampling and servicing.

EXPERIMENTAL DESIGN

The experiment was designed to investigate the effectiveness of various kinds of barriers placed in the soil to stop the penetration of plant roots or the burrowing by animals into simulated buried wastes. The barriers are cobble, concrete, asphalt, and urea borate (a root toxin). Lithium chloride was placed at 8 ft in the soil profile and cobalt chloride placed at 4 ft as chemical tracers. The tracers were placed just below the barriers, so root penetration through the barrier could be detected by analyzing plant tissue for these elements using a spectrophotometer.

A back-up tracer system was installed to be used in case the chemical tracer technique fails. Plastic tubes fitted with fittings used in subirrigation agricultural systems were buried within the lithium chloride and cobalt chloride layers, so that short-lived radioactive tracers could be introduced later in an aqueous solution as needed.

Two plot types were used in this study. To study the effectiveness of cobble to stop penetrations of both plant roots and burrowing animals a large trench, 0.04 hectare (0.1 acre) was partially filled with cobble and covered with soil, and then fenced to contain small animals within the study area. This plot will be referred to as the trench plot. The second plot type constructed in an adjoining ditch consisted of 28 concrete culverts that were buried vertically in the soil. This experimental design permitted a replicated study of the effectiveness of several plant root barriers. This plot will be referred to as the culvert plot. Seven treatments were replicated 4 times and randomly placed in 2 lines of 14 plots each. The 7 treatments are (1) control, natural soil; (2) a modified control, bentonite clay mixed with the surface layer of soil; (3) washed cobble (designed like the trench plot); (4) concrete layer; (5) asphalt mixed in deep layer of soil; (6) asphalt mixed in a shallow layer of soil; and (7) urea borate mixed in a shallow layer of soil.

As shown in Table 1, the soil used in these plots was very sandy, so 15 kg (33 lbs) of bentonite clay was mixed into the surface 6 in. of soil of all treatments except control (1). Bentonite was added to the surface layer of the soil to increase the water-holding capacity and cation exchange capacity of the upper root zone to assist in the revegetation procedure and encourage growth of shallow-rooted plants. The bentonite also serves to bind the surface soil into a crust which is less wind-erodible than the untreated soil.

TABLE 1. Typical Soil Characteristics of the Demonstration Area

Soil Depth (dm)	% Sand	% Silt	% Clay	% Org. Mat.	pH	Sol. Salt (mmhos/cm)
0-1	55	43	2	0.65	7.5	0.27
1-2	64	35	1	0.45	7.4	0.23
2-3	71	28	1	0.25	7.5	0.30
3-4	68	31	1	0.35	7.7	0.40
4-5	55	44	1	0.30	7.8	0.20
5-6	51	47	2	0.30	7.9	0.21

Cobble was selected as a barrier because of its ease of availability at most burial sites, its low water-holding capacity to discourage growth of deep-rooted plants, and its resistance to digging animals. Also, cobble layers are not subjected to cracking as are asphalt and concrete layers.

The concrete barrier was buried in the soil profile to help protect it from freezing and thawing, the main cause of cracking and weathering of concrete slabs. Asphalt emulsion has been previously used as a surface barrier to prevent plant growth and reduce wind erosion. If asphalt proves effective as a sub-surface root barrier, it has several advantages over concrete and cobble. It is cheaper than concrete and is easily applied as spray during the early stages of burial. Urea borate was chosen for study as a typical soil sterilant which can act as a root barrier. Its advantages are that it is easy to apply and cheaper than other root barrier types.

CONSTRUCTION AND SPECIFICATIONS OF PLOTS

Preparation for construction required modifying the trenches to the proper dimensions. The culvert plot was deepened to 2.4 m (8.0 ft) below grade and widened to 3.0 m (10.0 ft) at the bottom, for a length of approximately 27.4 m (90.0 ft). The trench plot was filled to 2.4 m (8.0 ft) below grade and widened to a width of 8.5 m (28.0 ft) at the bottom, for a length of approximately 64.0 m (210 ft). The unused remainder of the large trench was filled to grade level and compacted.

The construction of the trench plot (Figure 2) began with the placement of moisture probe wells. These wells were fabricated from 3.8 cm (1.5 in.) diameter electrical conduit 3.05 m (10 ft) in length, the bottom of which was capped. Five wells, extending to a depth of 2.9 m (9.5 ft) were placed along the center line of the trench, spaced evenly at a distance of 15.24 m (50 ft) from each other.

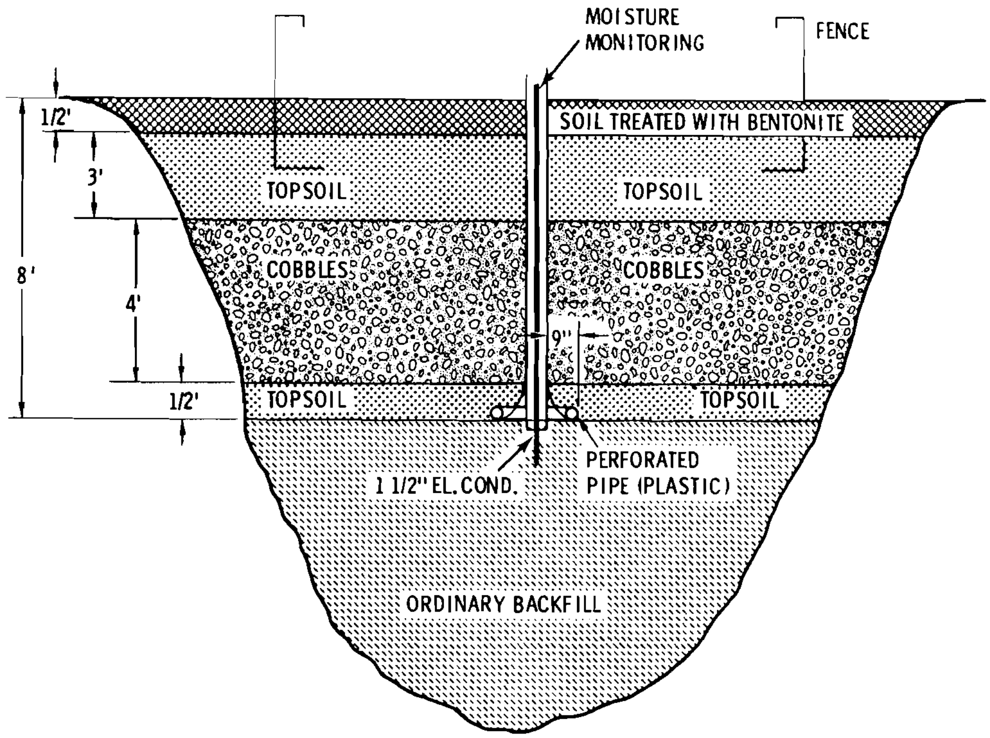

FIGURE 2. Sectional View Through Access Tube of the Trench Plot

Next, the lithium chloride tracer was added. It was mixed into a 1.22 m wide by 0.15 m deep (4 ft x 0.5 ft) strip down the center of the trench for a length of 61 m (200 ft). The concentration of the mixture was 50 ppm Li with soil by weight.

The back-up tracer system used in the trench plot consisted of two perforated pipes placed parallel to and 0.15 m (0.5 ft) 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 the 2.4 m (8.0 ft) depth, and ran the length of the trench. The vertical sections provide for introduction of chemicals from grade level to the horizontal section. The entire system was fabricated from 0.95 cm (3/8 in.) inside diameter plastic pipe.

The next step was the addition of a 0.15 m (0.5 ft) thick layer of topsoil to the whole trench. This was followed by a 1.2 m (4 ft) deep layer of 3.8 to 7.6 cm (1.5 to 3 in.) diameter rock. The top of the rock layer measured 6.1 m (20 ft) wide by 60.96 m (200 ft) long, with the sides being permitted to assume the natural angle of repose (Figure 3). Care was taken to prevent damage to the moisture probe wells during the addition of the cobble.

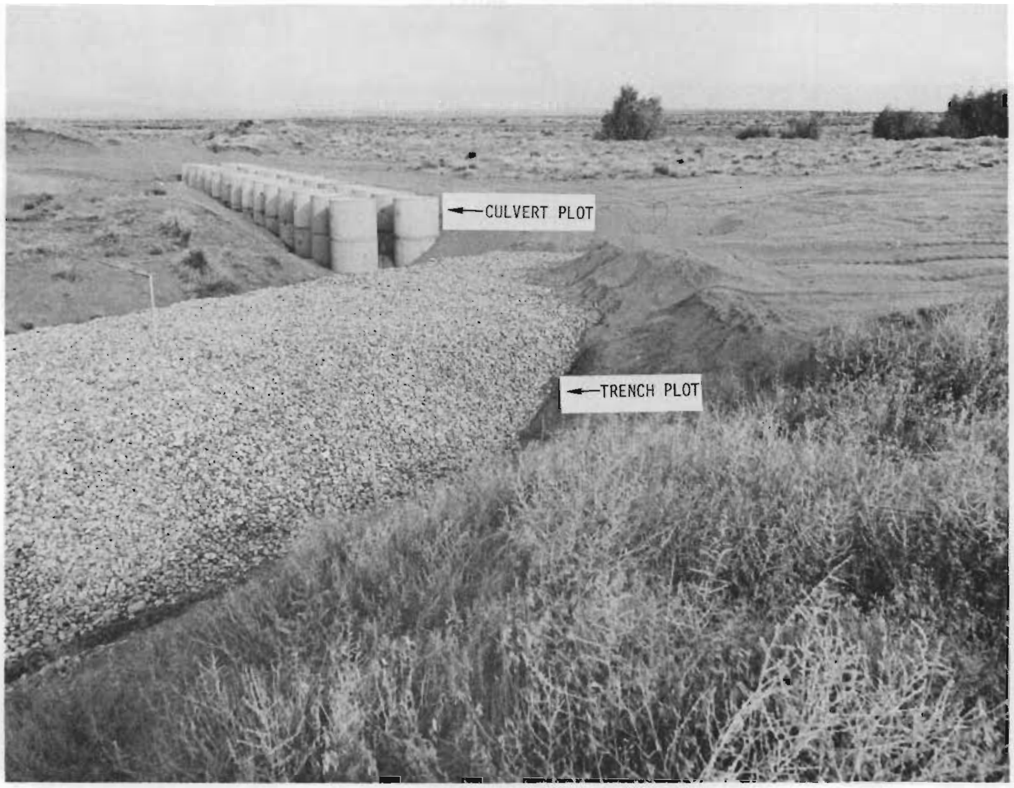

FIGURE 3. Location and Placement of Cobble Layer in the Trench Plot and the Arrangement of the Culvert Plot

The remaining 1.07 m (3.5 ft) of excavation were backfilled with topsoil, with the top 0.15 m (0.5 ft) being treated with bentonite..

The construction of the culvert plot began with the placement of steel-reinforced concrete culvert sections. The dimensions of the sections were:

Length - 1.22 m (4 ft)
Inside diameter - 1.22 m (4 ft)
Wall thickness - 12.7 cm (5 in.), approximately

The sections were placed in the culvert plot in two parallel lines of 14 each, two sections deep for a total culvert depth of 2.44 m (8 ft). After stacking, the seam between sections was sealed with concrete to isolate plots from their surroundings. A 1.83 m (6 ft) center-to-center distance was maintained between adjacent culverts. There was an allowed deviation of 2.5 cm (1 in.) from vertical over the 2.44 m (8 ft) length of a culvert.

Following the installation of the culverts, a moisture probe well was placed vertically in the center of each culvert. These wells were identical in dimensions and depth of placement to those placed in the trench plot. Lithium chloride was mixed into the soil at the bottom of each culvert as it had been in the trench plot.

Tracer apparatus made from perforated pipes were installed, one in each culvert. These pipes were similar to those used in the trench plot and consisted of two sections. A section of hollow solid-wall pipe of 3.05 m (10 ft) in length was followed by a section 13.7 m (45 ft) long, fitted with drip irrigation emitters and plugged at the end. The solid section followed the moisture probe well to the 2.4 m (8 ft) level and the emitter section was spiralled around the probe well in a regular pattern so that any radioactive or chemical tracer added would be spread evenly over the area of the plot.

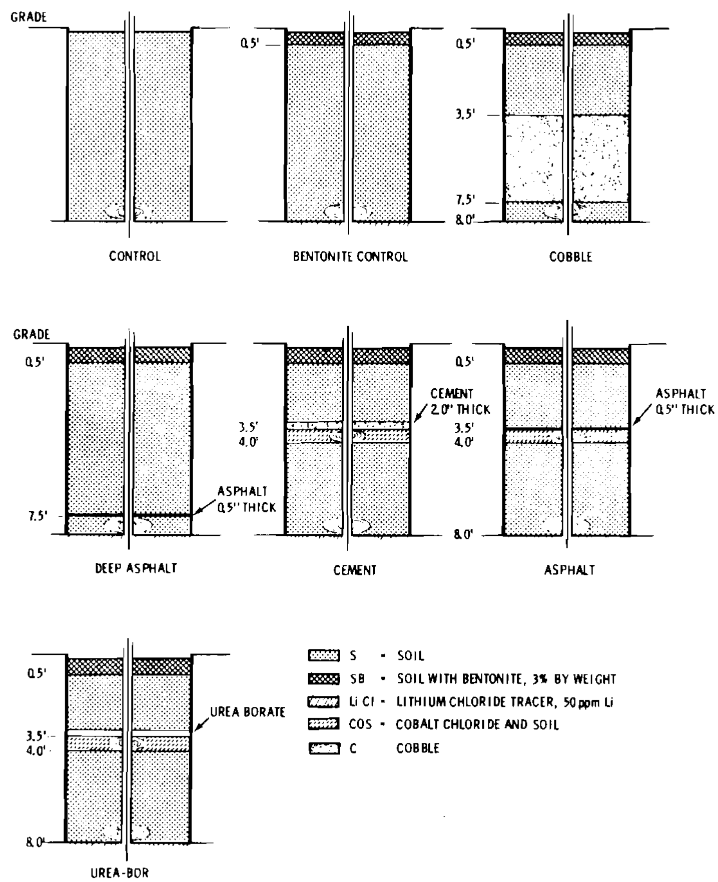

FIGURE 4. Schematic Drawings of the Placement of Bio-barriers and Tracer Apparatus in the Culvert Plot

Following these steps, the culverts were filled according to the type of treatment designated for that plot (Figure 4).

The control culverts were simply filled with topsoil and compacted enough to eliminate massive settling. The bentonite control plots were filled identically, except that the top 0.15 m (0.5 ft) were treated with 3% bentonite by weight.

The cobble culverts were filled with layers identical to those in the trench plot.

The deep asphalt culverts were backfilled with a 1.27 cm (0.5 in.) thick layer of asphalt incorporated at the 2.3 m (7.5 ft) level. The top 0.15 m (0.5 ft) were treated with bentonite.

The asphalt, cement, and urea-bor culverts were all backfilled with soil to the 1.22 m (4 ft) level. Soil (0.15 m) was mixed with cobalt chloride tracer and added; the cobalt concentration in this layer was 50 ppm.

A 1.27 cm (0.5 in.) thick asphalt barrier was formed in the designated culverts as follows: for each culvert, 3.8 liters (1 gal) of asphalt and 7.6 liters (2 gal) of water were mixed, and the resultant mixture was poured into the culvert at the specified depth. In the concrete culverts, a 5.08 cm (2 in.) thick barrier of concrete was poured. The barrier added to the urea-bor plots was a 5.08 cm (2 in.) thick layer of urea borate mixed with soil, at a rate of 170 g (0.4 lb) urea borate per culvert. All these layers were placed at the 1.07 m (3.5 ft) depth. These were then backfilled with topsoil, with the top 0.15 m (0.5 ft) being again treated with bentonite.

After all culverts were filled to grade level, the surrounding area, approximately 1 hectare (2.5 acres), was leveled. An access road was constructed to the trench plot and the culvert plots. Then the entire area was planted to cheatgrass. The surrounding area was later treated with a latex soil stabilizer, Dow M-166, to prevent serious erosion damage until the plants were established.

STUDY SCHEDULE

To test the barriers for root penetration, Russian thistle will be seeded in the trench plot and all the culverts during the spring of 1976. The above ground tissues will be harvested throughout the growing season and analyzed spectrophotometrically for lithium and/or cobalt. If either of these elements is found in the tissue at levels greater than control samples, it will be assumed that the roots have successfully passed through the barrier. During this time, soil moisture will be measured in the profile using a neutron probe. Moisture measurements have been scheduled as frequently as needed during the growing season and monthly during the remainder of the year.

After the Russian thistle experiment has been completed in 1976 and the animal-proof fence has been installed on the trench plot, small mammals will be captured and placed within the fenced area. Digging by the animals will be observed, and the excavated soil and animal hair will be analyzed for lithium and/or cobalt to determine if the animals dug through any of the barriers. The animal diets will be supplemented when necessary.

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