 LESSONS LEARNED FROM A BIOENGINEERING MANAGEMENT PILOT PROJECT ON A SHALLOW-LAND DISPOSAL TRENCH IN WESTERN NEW YORK

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ABSTRACT

The New York State Energy Research and Development Authority (NYSERDA) has completed a five-year Bioengineering Management Pilot Project on a waste disposal trench at the State-Licensed Radioactive Waste Disposal Area (SDA) near West Valley, New York. In response to rising leachate levels in waste disposal trenches at the SDA, options for controlling infiltrating water were investigated. As a result, the bioengineering Pilot Project was installed on a waste disposal trench to test the suitability of this technology at the SDA. The SDA Pilot Project marked the first test of the bioengineering technology on an actual waste disposal trench.

Bioengineering Management was developed under grants from the U.S. Nuclear Regulatory Commission on larger scale lysimeters at the U.S. Department of Agriculture's Experimental Station in Beltsville, Maryland. The bioengineering technology uses a combination of enhanced runoff and transpiration by plants to effectively eliminate infiltration of water. Impermeable cover panels reduce infiltration of precipitation; and shallow-rooted junipers, planted in narrow gaps between the panels, transpire the moisture that penetrates the soil surface.

Although initial studies at the Beltsville test facility showed that the cover system was viable, that investigation did not evaluate the effect of soil or climatic conditions, root penetration, radionuclide uptake and compatibility of plant species with soil profiles. At the SDA, the Pilot Project focused on the assessment of this technology through evaluation of changes to the internal and external trench environment, including: trench water levels; soil moisture in the trench cap; radionuclide uptake by vegetation; maintenance and repair needs; and the compatibility and suitability of the vegetation to climatic and soil conditions.

Results from the five-year Pilot Project showed that the bioengineering management technology is effective in reducing or eliminating percolation of water through the trench cap, and soil moisture levels can be reduced to depth even in northern temperate climates with compacted silty clay soils. Radionuclide monitoring showed that low levels of carbon-14 and tritium were taken up in the trench cap vegetation. In addition, the large density of the junipers planted on the cover (3,000 plants on 2,428 square meters), aided in the identification of potential threats to large plant monocultures. Throughout the project, the junipers were threatened by rodents and a pathogenic fungus commonly known as twig blight. The fungus and rodents killed or damaged a number of juniper plants and raised maintenance issues that must be addressed when using a nonstandard cap in a highly regulated environment.

Evaluation of the junipers during cover removal showed that the plant roots remained within the upper 60 cm of soil. The Pilot Project also provided the opportunity to compare the performance of bioengineering management to geomembrane covers, which were placed over the remaining trenches. Initial cost comparisons with geomembrane covers used at the SDA show that the bioengineered cover has slightly higher installation costs but both cover types require maintenance expenditures after installation.

The data acquired as a result of this study (e.g., trench leachate levels, radionuclide uptake, soil moisture profiles, maintenance, vegetative growth, root penetration, etc.) adds significantly to the available information obtained from prior tests at other sites. Although more data is needed in regard to the longer-term performance of a bioengineered cover system, this experiment has shown that the technology will perform in a humid climate with a short growing season. The Pilot Project also provided experience with management and maintenance of an innovative technology in a regulated environment. The results add to the knowledge base on innovative trench cap technologies and can serve as a basis for continued research on the application of the bioengineering approach.

INTRODUCTION

The New York State Energy Research and Development Authority (NYSERDA) has responsibility for monitoring and maintaining the State-Licensed Disposal Area (SDA), a shut-down, commercial radioactive waste disposal site at the Western New York Nuclear Service Center, located about 40 miles south of Buffalo, New York. The SDA received waste between 1963 to 1975. The unlined disposal trenches were excavated in the native silty-clay soil that is highly impermeable at depth, with a hydraulic conductivity of about 1x10^{-8} centimeters per second (cm/sec). The
waste was covered with a resistive barrier cap comprised of 2.5 to 3.0 meters of compacted clay soil, vegetated with
gress and sloped to direct runoff to drainage swales constructed between adjacent trenches. Typically, the trenches
are approximately 170 meters long, six meters deep, and vary in width from six meters at the bottom to 11 meters at
the top.

The area where the site is located receives about 109 cm/yr of precipitation. Because of the very low permeability
of the soils in the lower part of the trenches, water that permeates through the compacted clay trench covers tends to
accumulate in the trenches. Water infiltration rates through the grass-covered, silty-clay caps increased over time
due to factors such as weathering and subsidence. To slow water accumulation in the trenches, NYSERDA installed
exposed geomembrane covers over two trench caps in 1992. In looking at options for infiltration control
technologies, evapotranspiration (ET) covers were investigated, and Bioengineering Management was identified as a
potentially viable long-term trench cover alternative. Since the technology had not gone beyond the research stage,
it was decided to initiate a Pilot Project on a single trench to evaluate the technology’s suitability in the climate and
soils at the SDA. NYSERDA installed the Bioengineering Management Pilot Project on Trench 9 in 1993 and
performance of the cover was evaluated until it was removed from the trench in September 1999.

TECHNOLOGY DESCRIPTION

The bioengineering technology controls infiltration of water by placing impermeable panels, mounted on wooden
frames, over the trench cap to enhance runoff. Shallow-rooted junipers, planted in narrow gaps between the panels,
transpire soil moisture and prevent deep percolation of water through the trench cap and into the waste disposal unit.

The concept of Bioengineering Management was originally developed by Dr. Robert Schulz, University of
California at Berkeley, under grants from the U.S. Nuclear Regulatory Commission. Initial investigations were
carried out on small test plots at the Maxey Flats Radiological Disposal Site in Maxey Flats, Kentucky, from 1984-
1988 (1). Following the encouraging initial results, a large-scale field demonstration was established at the U.S.
Department of Agriculture's Experimental Station in Beltsville, Maryland (1987-present). The results of these
studies, which include water balance summaries, are described in NUREG/CR-4918 (2).

PROJECT OBJECTIVES

The objectives of the Pilot Project at West Valley were to prevent vertical water infiltration through the trench cap,
evaluate whether this technology is effective in the soils and climate that exist at the West Valley site and evaluate
the maintenance requirements associated with the bioengineered cover in relation to more conventional alternatives.

INSTALLATION EXPERIENCE

Design work for the bioengineered cover at the SDA began in 1992 and was completed with the assistance of Dr.
Schulz and local horticultural experts. The initial design was reviewed and permitted by the New York State
Department of Environmental Conservation before starting installation and monitoring of the project.

Trench 9 was selected for the Pilot Project because water level data showed that Trench 9 was hydraulically isolated
from adjacent trenches (water entered the trench vertically, through the trench cap). Furthermore, prior to
installation of the bioengineered cover, leachate levels were rising in Trench 9 at a slow, consistent rate. This made
it possible to observe changes in infiltration rates without having to conduct detailed water balance studies after
installation of the cover.
To prepare for installation of the cover, the surface of Trench 9 was graded, and 20 to 30 cm of top soil was added to
accommodate the junipers and to adjust the slope of the surface for hardcover placement. Two hundred and fifty
hemlock wood frames were placed across the trench cap to serve as mounting frames for the panels as well as to
keep the panels off the surface of the trench. Before selecting hemlock for the frames, several different materials
were investigated, including pressure-treated lumber and Polyvinyl Chloride pipe. The rough-cut hemlock was
selected because of its resistance to rotting, low cost and ability to provide a satisfactory design life with minimal
labour costs. The frames were secured to the trench cap with earth anchors. Approximately 2,900 Hetzi junipers and
100 Pfitzer junipers (the species used at the Beltsville test facility) were planted between the anchored hemlock
frames. Following planting of the junipers, 8 oz/ft2 gray fiberglass panels (50 inches x 18 feet) were attached to the
hemlock frames.
Drainage swales located along the sides of Trench 9 carry precipitation runoff from the trench cover away from the disposal trench to a nearby creek. During construction of the Pilot Project, the drainage swales along both sides of the trench were regraded and lined with a hypalon membrane to prevent runoff from percolating into the trench. The drainage swales were reworked early in the project to keep water from accumulating under the liner and reworked again to accommodate the installation of geomembrane covers on adjoining trenches in 1995.

Construction began in August 1993 and was completed in October 1993. Figure 1 shows an aerial view of the SDA in 1998, the bioengineering Pilot Project shortly after installation in September 1993 and the Pilot Project just prior to removal in July 1999.

PROJECT MONITORING

Because of the experimental nature of the Pilot Project, NYSERDA initiated an environmental monitoring program that may not have otherwise been required on a conventional cover system. Regulatory requirements also mandated certain monitoring activities, primarily to assess radionuclide uptake from the junipers.

Monitoring activities focused on the assessment of environmental and other parameters that would provide an indication of the performance of the cover system. Parameters that were monitored included: leachate elevation in the trench; moisture content of the trench cap soils; concentration of radionuclides in the air; concentration of radionuclides in the junipers; the general health of the junipers; evidence of nuisance animals; condition of the hardcover; climatic conditions (rainfall, temperature, etc.); control and maintenance of runoff water.
Each physical component of the bioengineered cover (junipers, hemlock frames and fiberglass panels) was visually checked and the environmental data were collected and assessed to monitor for changes that occurred as the plants became established on the trench. Through the monitoring program, cover performance was assessed to determine whether the system was eliminating or reducing deep percolation of precipitation through the trench soil cap and to determine how the plants and other cap materials performed over time.

PROJECT RESULTS

Trench Water Elevations

During the five year pilot project, leachate elevations in Trench 9 were measured monthly to observe changes in the rate of water accumulation attributable to the installation of the bioengineering cover. As shown in Figure 2, Trench 9 leachate levels stabilized after the cover was installed. The change from slowly increasing leachate levels to stable leachate levels indicates that the bioengineering cover was effective in reducing water infiltration through the trench cap. Statistical trend tests showed that there was a significant change in the leachate level trend after the bioengineering cap was installed on Trench 9.

After approximately 2 years of stable leachate levels in Trench 9, leachate levels were observed to begin decreasing (see Figure 2), and that trend continued through the time the cover was removed in 1999. Because there is a continuous slow, downward movement of water toward the underlying clay, the water level in a trench will exhibit a decreasing trend if the trench cap effectively prevents water from entering the trench. The downward trend in the Trench 9 leachate level coincided with two events that affected the caps on or near Trench 9. First, geomembrane covers were installed over the remainder of the grass covered trenches, including the two trenches immediately adjacent to Trench 9. These new geomembrane covers may have eliminated a pathway for water entering through the sides of Trench 9. Alternatively, the decreasing trend began at the time that the junipers on Trench 9 recovered from earlier rodent damage (discussed below). It is possible that increased evapotranspiration due to the recovery of the plants improved the efficiency of the Trench 9 cover in limiting water infiltration, resulting in the decrease.

![Figure 2: Trench 9 Leachate Elevations, 1984-1999.](image-url)
Plant Performance

Routine visual inspections were conducted weekly to identify changes in the junipers, hemlock frames and panels.

Juniper growth and survival became significant concerns during the pilot study due to potentially devastating fungus and rodent infestations. During the winter of 1993-1994, small rodents (e.g., field mice, shrews, etc.) damaged 70-80 percent of the 3,000 junipers, killing approximately three percent of the plants. The damage was caused by rodents girdling the plants’ main stem and removing branches from the young junipers. Efforts to control the problem with rodenticides or other chemical control measures were not pursued due to the complexities of applying regulated chemicals on a radioactive waste disposal site. The rodent damage decreased in years to follow as the junipers matured; and, by 1996, damage was evident only on small branches above the hardcover panels. Approximately 100 junipers were replaced in those rows where all or most of the plants were lost to provide vegetative cover and to maintain evapotranspiration to prevent localized wet areas. The damage to the surviving junipers may have slowed the ability of the plants to dry out the clay cap soils, but the plants showed a remarkable ability to recover.

Another threat to the junipers was identified in the spring of 1997. At that time, the junipers were infected with a fungus known as Kabatina juniperi, commonly known as twig blight. According to horticultural experts, the fungal spores likely entered the plants through wounds caused by the rodents or chafing on the hardcover panels. Within a year, the Kabatina blight had affected the majority of the 3,000 junipers on the trench cover to various degrees and completely eliminated living vegetation on approximately five percent of the plants. The recommended approach to treat the fungus was to prune and remove the affected plant tissue annually. While fungicides to treat Kabatina existed, studies showed that they were not very effective.

 Due to issues resulting from the presence of low levels of tritium and carbon-14 in the junipers, the plants were not pruned and it was decided to let the project progress without treating for the Kabatina fungus. By the summer of 1999, symptoms of the fungus had nearly disappeared and plants previously thought to have been killed by the disease began to show new growth. The juniper recovery was not anticipated even by plant experts and may have been due to the unusually dry spring and summer weather inhibiting the spread and growth of fungal spores.

Routine inspections showed that the cover was not a preferred habitat for small animals, but it was used for forage when other more preferred food sources were not available. During cover removal, only one rodent burrow was found in the trench cover.

In regard to the depth of root penetration, measurements of the juniper roots at the time of removal indicated that the plants developed shallow, lateral root structures, extending out on average to approximately 120 cm. Root depth did not exceed 60 cm for any plant measured or observed.

Soil Moisture

Soil moisture was monitored to identify trends in soil moisture changes resulting from the cover performance. When soil moisture increases at depth over time, precipitation has exceeded the ability of ET and runoff to remove water from the cap. Conversely, when soil moisture decreases over time, ET and runoff have exceeded precipitation. Regardless of the rate of change, either long-term trend is a measure of the effectiveness of the cover system. In the absence of water balance studies, soil moisture measurements provided a means to indirectly monitor the influence of the bioengineered cover on infiltrating precipitation.

Soil moisture was measured monthly (from March through November) at three locations on the bioengineered cover (Trench 9), along with single locations on two nearby membrane covered trenches that were grass covered when the project began (Trenches 8 and 10), and one location on a geomembrane-covered trench (Trench 13). By measuring soil moisture on these trenches, the performance of the bioengineered cover could be compared to the more conventional covers. Measurements were made at one-foot increments from one-to-five feet below the trench cap surface.

Figure 3 shows soil moisture profiles at five depths for the three monitoring locations on Trench 9. Soil moisture drying trends appear at location 9M (located at the middle of the trench) and 9S (located at the south end of the
trench). At location 9M, the annual average soil moisture level in the upper 30 cm of cap soil was reduced by nearly half, and the next horizon, the 60 cm level, was reduced by 25 percent. Although location 9S had somewhat less dramatic reductions, all the measured depths within the soil profile at both 9M and 9S showed decreasing soil moisture levels since 1996. Due to an unusually dry year in 1995, when annual rainfall was 30 cm below the average, soil moisture at all the Trench 9 measurement locations decreased, most probably as a result of the dry weather. The return to normal precipitation levels may have caused the trend results to show a slight increase for the following year before resuming the steady decreases observed for the remaining years resulting from the bioengineered cover performance.

Soil moisture measurements taken at location 9N, on the northern portion of Trench 9, did not indicate any pronounced trends during the monitoring period. A possible reason for the lack of notable soil drying at this location may be that this portion of the cap was severely impacted by rodent damage during the first two years of the project and was also the hardest hit by the twig blight. The soil moisture data collected from 9N showed an upward trend in soil moisture for the upper 90 cm of soil during the second through fourth years of the study. Soil moisture at the remaining depths stayed relatively constant during the same period. During the last year of the study, when it appeared the junipers were growing well and had recovered from both rodent and twig blight damage, soil moisture decreased at all but the deepest measurement depth (150 cm).

Geomembrane covered trenches (8, 10 and 13) maintained a relatively consistent soil moisture profile.

Radionuclide Uptake

Vegetation samples were collected monthly to evaluate the uptake and retention of mobile radionuclides in the junipers on Trench 9 and at a control location outside the SDA. Vegetation was evaluated for carbon-14 and tritium; and quarterly, for gamma emitting radioisotopes, gross beta, and gross alpha activity. Grass samples were collected while the grass-covered caps were present for comparison with juniper vegetation. Results of vegetation sampling showed only tritium and carbon-14 (C-14) present in the junipers, and it is likely that the presence of these radionuclides is related the movement of carbon dioxide and water vapor through the clay cap. Figure 4 shows that concentrations of these two radionuclides were consistently higher than those measured in the grasses from the control location. Concentrations for tritium and C-14 in the junipers remained relatively stable throughout the monitoring period. A 1994 sampling event of the grasses from SDA trench caps, before they were covered with geomembranes, show that the grass covers had comparable or higher levels of tritium and C-14 (see Table I) than the junipers.

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<th>Location*</th>
<th>C-14</th>
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* - Samples were collected from random locations along the entire length of the trench
Figure 3: 1994-1998, Soil Moisture Levels on Trench 9

Location 9N: Annual Average Soil Moisture Levels

Location 9S: Annual Average Soil Moisture Levels

Location 9M: Annual Average Soil Moisture Levels
Air Monitoring

Air near the Pilot Project was continuously sampled and evaluated weekly for radionuclide concentrations that may have resulted from Trench 9 or from other site emissions. Air samples were collected by a fixed-air monitoring station located on the southern end of Trench 9. The air monitoring station was positioned along a predominant wind direction and it continuously sampled air through charcoal and glass fiber filters and a silica gel column.
Ambient air sampling results were compared to background locations used to evaluate air quality for the adjacent West Valley Demonstration Project (3). Statistical tests performed on tritium results for Trench 9 and background data showed that the tritium data from the sampler on Trench 9 was slightly elevated above tritium data obtained from the furthest background location. At this point it is not clear that the elevated tritium levels are related to the release of tritium from the junipers or whether other site facilities contributed to the slightly elevated levels. Air monitoring will continue to see whether the removal of the junipers has any affect on the ambient air tritium concentrations.

**Durability of Cover Materials**

Weekly visual inspection of the bioengineered cover materials (panels, frames and anchors) during removal, showed no significant degradation in any components, leaving no indication that increased maintenance activities would have been immanent. The lack of degradation in cover materials, and the low maintenance requirements may possibly be attributed to the short duration of the test period in light of the overall life expectancy of the cover materials. In addition, the large vegetative crowns, characteristic of junipers, appeared to protect the cover panels from degradation due to ultra violet radiation.

**CONCLUSIONS**

The Pilot Project provided valuable data on the use and application of the bioengineering technology in the climate and soils at the SDA. The information gained through the project extends the information generated through the work performed at the Beltsville test facilities (2) by providing observations and data collected on an actual disposal trench. The work also shows that the technology is viable in a wide range of climate, soil, and moisture conditions in a humid northeast location with a short growing season.

Leachate level and soil moisture data showed that the bioengineered cover system effectively limited the infiltration of water and promoted drying in compacted silty-clay soils, even in the humid western New York climate. This drying provides a buffer for infiltrating water and increases the soil cap storage capacity in the event of failure of some component of the cap system. Soil moisture data from the geomembrane covered trenches showed a flat moisture profile, indicating that moisture remained in the cap.

Maintenance requirements were not significant for either the bioengineered or geomembrane covers. Since maintenance requirements were not significant for either cover type, costs were also low, with no one cover type offering an advantage over the other. Installation costs for the bioengineered cover were slightly higher than for geomembrane covers.

Throughout the five-year investigation, juniper growth had been threatened by both pathogens and rodents which presented management challenges that had not been anticipated. Although the junipers recovered from both threats without intervention, the potential use of fungicides and rodenticides and the management of plant trimmings containing low levels of radionuclides requires careful planning and coordination with consideration given to regulatory requirements.

Based on the experience gained through the Pilot Project at the SDA, additional investigation of the following issues is recommended for consideration of broader application of the technology:

- Are large monocultures preferred for such an application, given their susceptibility to disease or other damaging environmental factors?
- What other vegetation would be successful in an ET cover in a humid environment?
- Can the cover be successful with a natural succession of vegetation?
- How vital is the hardcover and to what extent does it have to be maintained after the vegetative cover has been established?
- What effects do soil type and consistency have on the maintenance of cover vegetation?
- Do the ET cover components eliminate the need for a resistive clay barrier?

Alternative ET covers are being investigated by other agencies to provide long-term, cost effective, landfill covers that will perform better than traditional grass-covered, resistive layer caps or geomembrane covers. At this time,
alternative ET cover systems can be subject to regulatory oversight not normally required with conventional covers and site managers may be required to provide additional monitoring and performance data. The Pilot Project at the SDA provided data that showed that bioengineered covers can perform well in a humid northeast environment with a short growing season. The project also identified issues that should be further assessed when considering broader application of the technology. The assessment of these issues, along with longer-term performance data, will help to gain further regulatory and industry acceptance of this promising technology.

REFERENCES

