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Four-year performance evaluation of a pilot-scale evapotranspiration landfill cover in Southcentral Alaska

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ABSTRACT

Alternative landfill covers utilizing evapotranspiration (ET) as the primary mechanism for protecting the waste layer from aerial moisture represent promising tools for cold region solid waste management. However, ET covers have not been evaluated for use in subarctic climates. As the functionality of an ET cover is driven primarily by climactic variables, climate-specific field tests are required prior to widespread implementation. The objective of this study was to evaluate the four-year performance of two competing pilot-scale landfill covers built atop drainage lysimeters near Anchorage, AK. The compacted soil cover (CSC) was designed and constructed according to standards prescribed by Alaska solid waste regulations. The alternative ET cover design was based upon a preliminary modeling study. After four years, the two adjacent lysimeters had each received a total of 1636 mm precipitation. Over that period, 201 mm moisture drained from the ET lysimeter, compared to 292 mm in the CSC lysimeter. The difference in drainage rates between the two covers was most apparent during the autumn season, when the drainage rates for both covers were at their annual maximum. The lower autumn and annual drainage rates observed in the ET lysimeter after the first year were potentially due to higher moisture storage capacity in the ET cover soils and/or formation of preferential flow paths in the CSC soils. Analysis of soil temperature, precipitation, and drainage data indicated that negligible amounts of winter precipitation infiltrated the ET cover during winter, and that the frozen soils promoted runoff over drainage during the spring melt. These results indicate that similar ET cover designs merit consideration for broader use in subarctic conditions.

1. Introduction

Subarctic communities in Alaska and elsewhere face a host of challenges with respect to the long term management of municipal solid waste. One common challenge is the installation of an effective final cover to minimize drainage of moisture into stored wastes. While conventional geomembrane covers will reduce drainage, many cold region communities do not have the economic resources to install and maintain a modern geomembrane-based cover system. Conventional compacted soil covers (CSC), while less expensive than geomembrane covers, suffer from preferential flow resulting from frost or desiccation cracking and may not be suitable alternatives (Albright et al., 2006). A practical alternative for long term management of solid wastes in many cold region communities would be a cover that could be constructed from local borrow sources, did not rely upon compaction to provide a moisture barrier, and minimized drainage of aerial moisture. Evapotranspiration (ET) covers, engineered systems relying on soil moisture storage and evapotranspiration processes rather than flow-resistant barriers, can potentially meet these criteria.

ET landfill covers are receiving increased attention in the United States and abroad as a practical solid waste management solution. The U.S. Environmental Protection Agency's Alternative Cover Assessment Program (ACAP), for instance, utilized drainage lysimeters to evaluate a range of alternative cover designs in eleven different locations around the contiguous United States (Albright et al., 2004). The results demonstrated that ET covers in arid, semiarid, or subhumid climates were generally effective at limiting drainage of moisture through the covers, while ET covers in more humid locations were less effective. Similar promising results have been reported over a wide range of arid and semiarid locations (Bohnhoff et al., 2009; Dwyer, 2003; Fayer and Gee, 2006; Nyhan, 2005). More recently, researchers demonstrated that ET covers in Ohio and other humid locations can be considered effective if drainage objectives are relaxed in regions with higher annual precipitation (Barnswell and Dwyer, 2011).

While ET covers hold promise for cold region communities due to their use of local materials and relative ease of construction, their effectiveness has not been well-characterized for use in the subarctic.

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Although the summer season in interior Alaska is considered to be arid or semiarid (Jätzold, 2000; Oechel et al., 2000), moisture infiltrating the soil surface during the spring snowmelt and heavy autumn rains could increase drainage through an ET cover. In order to establish ET covers as viable solid waste management solutions in subarctic regions, comprehensive evaluations such as the one described here are required.

The objective of this study was to evaluate the performance of a pilot scale ET cover and a pilot scale CSC cover in Southcentral Alaska. Specifically, the study was designed to provide results informing the installation of a field scale ET landfill cover at a site in Anchorage, Alaska. According to Alaska regulations, an alternative cover (e.g., ET cover) must inhibit the downward flow of aerial moisture at least as effectively as a prescribed cover in order to gain final closure approval. As a CSC represented the least costly prescriptive alternative for the landfill under investigation, this study evaluated the drainage performance of pilot scale ET and CSC covers in order to ascertain whether one was more effective than the other. An ancillary objective was to more completely characterize the function of an ET cover in a cold environment in order to evaluate their potential for broader use in arctic and subarctic regions.

2. Experimental setup

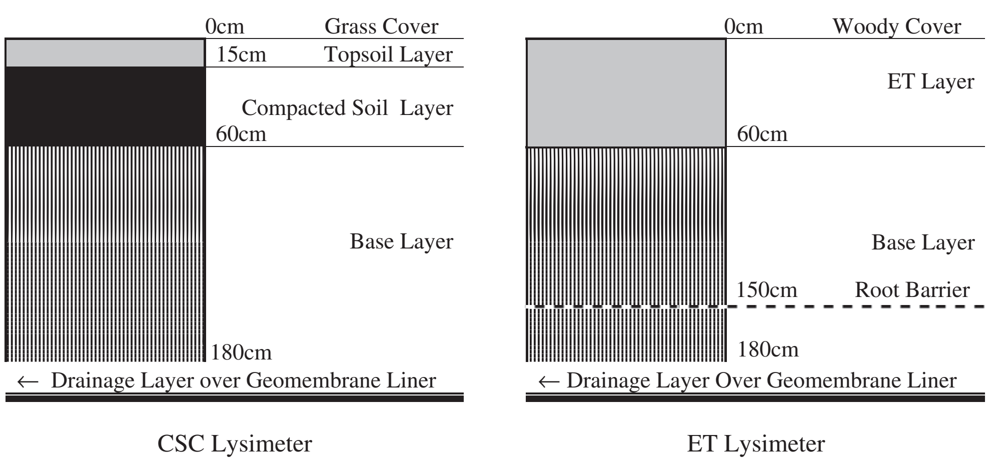
Two drainage lysimeters were constructed in 2004 to test the drainage performance of competing landfill cover types. The lysimeter profiles are depicted in Fig. 1. The lysimeters were based upon similar designs employed in the USEPA Alternative Cover Assessment Program (Benson et al., 2001). Details of the lysimeter design and installation are provided elsewhere (Munk et al., 2011; Schnabel et al., 2012).

In brief, one lysimeter contained a 60 cm CSC cover designed according to specifications prescribed for a Class II landfill (i.e., accepting <18 t of waste daily) by state regulations (State of Alaska,, 2010). The CSC cover was composed of three 15 cm lifts of silt (USCS-ML) compacted via vibratory plate compactor to yield a saturated hydraulic conductivity (K_{sat}) less than 10^{-5} cm/s. Two flexible wall permeameter tests (ASTM ID: D5084) of the compacted layer soils immediately following installation yielded K_{sat} values of 2.7×10^{-6} cm/s and 6.4×10^{-6} cm/s. Dry bulk density of the compacted layers was found to be approximately 1.65 g/cm^3. The CSC also contained a 15 cm layer of uncompacted topsoil overlaying the compacted layers to support growth of herbaceous vegetation and control erosion.

The ET cover design was based upon the results of an unpublished preliminary modeling study conducted by CH2MHill, a project consultant. The study's authors utilized the Simultaneous Heat and Water (SHAW) model (Flerchinger and Saxton, 1989) to demonstrate that an approximate 60 cm layer of vegetated forest soils would inhibit moisture at least as effectively as would a prescriptive CSC. Consequently, the second lysimeter was capped with a 60 cm ET cover consisting of minimally-compacted, organic-rich forest soils. The ET soils were classified as silts and silty sands (USCS-ML and USCS-SM), and placed using low ground pressure equipment at 80% to 90% of maximum proctor density as determined by ASTM ID: D698. The ET cover was placed in two 30 cm lifts. In addition, the ET lysimeter contained a root barrier at 150 cm depth to discourage root penetration into the drainage system. Deep root penetration was not anticipated to be a problem in the CSC lysimeter, so a root barrier was not used on the CSC lysimeter. As the impregnated-fabric root barrier was permeable to moisture, the root barrier in the ET lysimeter was assumed not to impede moisture flow or impact drainage results.

Both lysimeters contained a 120 cm base layer of identical soils to minimize bias resulting from capillary effects in the drainage system. The base layers were obtained from a local borrow source, and contained a mixture of sandy silts (USCS-ML) and silty gravels (USCS-GM). The footprint of each lysimeter was 19.8 m × 10.7 m, and the depth was 1.8 m. The lysimeters were circumscribed by lined berms to facilitate the capture of runoff moisture. In order to emulate the thermal conditions of the surrounding soils, the final lysimeter surface elevation was equal to that of the surrounding grade.

The lysimeters were instrumented with metering devices to continuously measure surface runoff and subsurface drainage. In addition, the ET lysimeter was instrumented with five thermistor strings throughout its depth to provide soil temperature information. A weather station was installed at the site to continuously measure precipitation, air temperature, wind speed and direction, net radiation, photosynthetic active radiation, relative humidity, and barometric pressure. Upon completion, the CSC lysimeter was hydroseeded with a grass mixture suitable for growth in Southcentral Alaska. The ET lysimeter was planted with a mixture of saplings containing 40%



Notes: Compacted Soil Layer = USCS – ML, average K_{sat}=4.6x10^{-6} cm/sec
Base Layer = USCS – SM and USCS – GM
Topsoil and ET Layer = USCS–SM and USCS-ML with high organics and minimal compaction
Root Barrier = Reemay Biobarrier
Drainage Layer = GSE Fabrinet
Geomembrane Liner = Layfield PP36 (0.91mm polypropylene)

Fig. 1. Profile of CSC and ET lysimeters.