Performance evaluation of synthetically lined landfills

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ABSTRACT: Landfill design and performance standards for new facilities frequently require the use of geomembrane composite and double liners. Performance data from synthetically lined landfill sites have not been widely available. This report presents data obtained by monitoring three recently constructed synthetically lined landfill sites. Quantities of leachate removed by the primary and secondary collection systems from these landfills were tabulated. The data show that properly designed and constructed synthetic landfill liners provide effective containment of leachate. The environmental protection provided by synthetic liners is equivalent or superior to that of typical clay-lined facilities.

KEYWORDS: High density polyethylene, land fill, liners, performance evaluation.

Landfill liner designs are constantly refined as performance data become available. Clay-lined landfill construction methods and construction quality-control procedures have been researched (*1*, *2*), and field performance data reported (*3*). Synthetic liner materials have been used in clay-deficient areas and, more recently, to construct composite landfill liners. While the relative benefits of different synthetic liner materials have been widely debated (*4*), actual performance data from synthetically lined facilities are not well publicized.

Three Upper Midwest landfills, each containing double synthetic liners with both primary and secondary leachate-collection and-removal systems, constructed during 1990 and 1991, have been monitored to determine the quantity of fluid passing through the primary high-density polyethylene (HDPE) liner. Two of the landfills receive primarily paper sludge and ash, while the third receives baled municipal solid waste (MSW). The primary (top) liner at each site was constructed of 1.5-mm (60 mil) HDPE. The secondary liners at the two paper sludge landfills are identical to the primary liner, while the MSW landfill has a composite secondary liner consisting of 1.5-mm (60 mil) HDPE over a bentonite-enriched soil liner.

The design concepts and construction methods used at each site will be described. Construction quality control/construction quality assurance (CQC/CQA) procedures were similar for each site. The primary focus of this report is to assess the effectiveness of HDPE liner systems based on recorded volumes from primary and secondary leachate collection systems. Performance data are also compared with similar data from clay-lined landfills.

Site construction

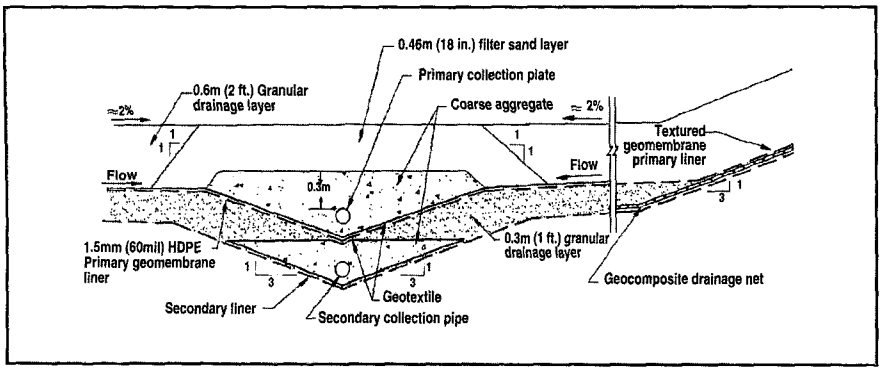
Site A

The Site A landfill expansion, constructed in 1990, included a lined area of 2.82 ha (6.96 acres) with a perimeter-confining dike rising 16.5 m (54 ft) above the cell floor on one side. This slope was graded at a pitch of 3H:1V (18.4°). The as-constructed liner cross section at this site is illustrated in **Fig. 1.**

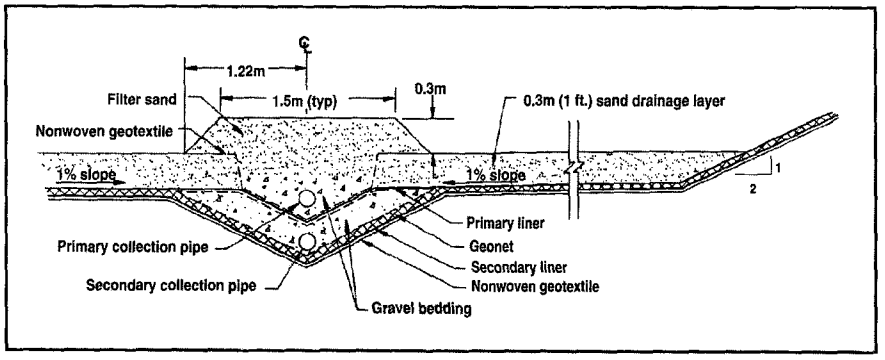
Polyvinyl chloride (PVC) piping systems are incorporated in both the primary and secondary leachate collection and removal systems. On the 3H:1V side slope, both HDPE liners were constructed using textured HDPE, and the secondary leachate collection layer of sand was replaced with a 6.5-mm (0.25 in.) thick polyethylene geonet drainage medium, with a 142-g/m^2 (6 oz/yard^2) nonwoven geotextile heat-bonded to both sides. The primary and secondary liners are continuously sealed to each other around the cell

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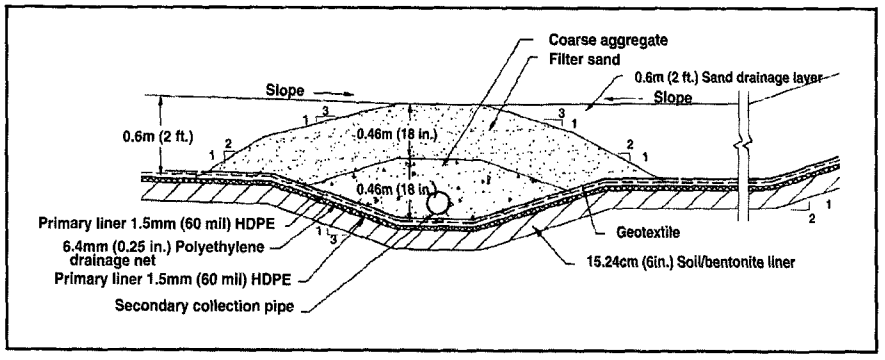
1. Site A liner cross section (not to scale)



2. Site B liner cross section (not to scale)



3. Site C liner cross section (not to scale)



perimeter to prevent infiltration or exfiltration.

Construction at Site A occurred between June and October 1990. All work was performed in accordance with proven CQC/CQA procedures. Site A operation began in March 1992, with the waste stream typically composed of primary and secondary paper sludge dewatered to approximately 35% solids, along with smaller quantities of dry boiler ash, lime mud, and wood waste.

Site B

Site B is situated in an area of coarse glacial till, typically classified as silty gravelly sand, over 23 m (75 ft) in thickness above the bedrock surface. Construction of the 2.49-ha (6.15 acre) expansion to this 10-ha (25 acre) site began during the fall of 1990. Previously placed uncontrolled fill soil and wet weather required substantial undercutting of the subgrade and replacement with compacted soil to restore the subgrade and form the perimeter confining dikes. The cell floor is between 4.6 m and 7.6 m (15 ft and 25 ft) below the top of the surrounding dikes, with base slopes averaging 1%. Internal dike slopes have an average pitch of 2H:1V (26.6°).

Figure 2 depicts the as-constructed liner cross section at Site B. Both primary and secondary liners consist of smooth 1.5-mm (60 mil) HDPE separated by a 6.5-mm (0.25 in.) thick geonet drainage material. The primary and secondary liners are continuously sealed to each other around the cell perimeter to prevent infiltration or exfiltration. A single drainage pipe, surrounded by stone and geotextile, runs the length of the cell to remove drainage in the secondary collection layer. A 284-g/m^2 (12 oz/yard^2) nonwoven geotextile covers the entire subgrade to protect the secondary liner from the coarse textured on-site soils.

A central leachate collection header pipe and collection laterals, spaced at 30.5 m (100 ft), are used to remove leachate from the 0.3-m (1 ft) thick sand drainage blanket placed above the primary liner. The liner side slopes are not covered. Each collection lateral is fitted with a perforated cleanout riser on the dike side slope to speed the removal of surface water.

Construction of internal ash containment dikes prior to waste filling subdivided the cell into three equally sized areas. Site B accepts both dry boiler ash and a combined primary and secondary sludge dewatered to an average of 30% solids. Waste disposal in Site B began in November 1991.

Site C

Work at Site C involved construction of a 1.74-ha (4.3 acre) expansion to an existing MSW landfill. Bedrock outcrops exist just north of the cell, and bedrock is over 12 m (40 ft) below the ground surface near the south edge of the cell. Outwash sands are prevalent over a veneer of highly weathered rock above the bedrock surface.

The perimeter dike on one side of this cell rises about 3 m (10 ft) above the cell floor, with smaller internal containment dikes on the remaining three

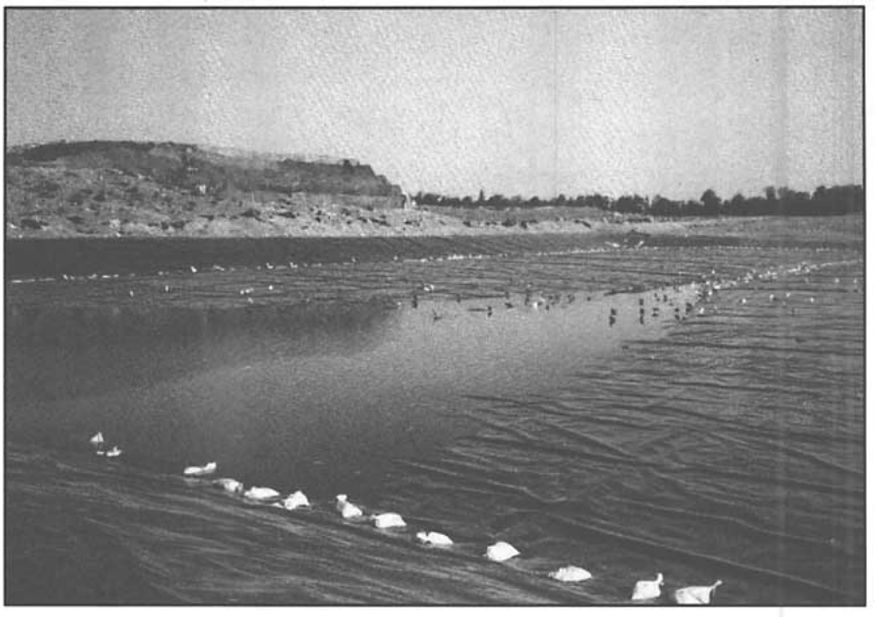
sides. All side slopes are 3H:1V.

Figure 3 shows the typical liner cross section at Site C. The Site C secondary liner is a composite of 1.5-mm (60 mil) smooth HDPE over a 15.24-cm (6 in.) thick compacted-soil/bentonite liner. A 6.5-mm (0.25 in.) thick geonet was placed over the entire cell floor and dike slopes to provide secondary leachate collection and removal. The 1.5-mm (60 mil) primary HDPE liner was covered with a geotextile and 0.6 m (2 ft) of processed sand and a piping network comprising the primary leachate collection and removal layer. Both the primary and secondary HDPE liners are sealed together at the cell perimeter to prevent infiltration and exfiltration.

Construction procedures and CQC/CQA were similar to those at Sites A and B. The hydraulic conductivity of the soil/bentonite liner, measured by laboratory tests (ASTM D 5084), was less than 1×10^{-7} cm/s. Considerable difficulty was encountered while installing the HDPE secondary liner on the soil/bentonite liner because of wet weather and intrusion of bentonite dust or mud into the liner surface where adjacent panels were welded together.

After completion of the primary liner at Site C, a 1577-m^2 (17,000 ft^2) area of the cell floor was flooded with water from the nearby sedimentation basin. A container placed in the secondary collection system manhole collected water that leaked through the primary liner. This water was removed through the transfer pipe in the secondary collection system sump. This test was continued for a 5-day period during which an average of 3.28 L/ha/day (0.35 gal/acre/day) were collected. **Figure 4** depicts this field-leakage test. Disposal of baled MSW in Site C began in late February 1992.

4. Site C—field-leakage test



Landfill performance data

Precipitation data were gathered for each of the three sites, and the monthly contribution to the leachate volume calculated. In a similar manner, the monthly leachate volume removed from each site was divided by the lined area of the cell to allow calculation of the leachate quantity in units of liters per hectare per day (L/ha/day). The same procedure was used to calculate the quantity of water collected in the secondary leachate collection system to allow for a comparison of the sites on an equal basis. The monthly data and site averages are summarized in **Tables I–III** for Sites A through C, respectively.

At Site A, volumes for both the primary and secondary leachate collection systems were calculated from hourly meter readings on pumps. At Site B, the secondary leachate volume was physically measured by accumulation in a sump, and the leachate volume was measured in a tank truck of known volume. At Site C, the secondary leachate volume was calculated from hourly meter readings on the pump, and the leachate volume was measured in tank trucks.

Table I shows that the primary leachate volume collected at Site A was generally less than the volume of precipitation prior to February 1992. After waste disposal in Site A began (March 1992), leachate production volumes exceeded precipitation volumes. We attribute a portion of this increase in the leachate volume to surface runoff from the adjacent cell entering the new cell because of the contiguous filling methods used. Table II shows that leachate production volumes at Site B averaged 80% of the precipitation volume. Table III shows that leachate production volumes at Site C averaged less than 50% of the impinging precipitation volume. Use of soil and synthetic intermediate cover materials over a significant portion of Site C, and the absorptive capacity of the baled MSW, are likely reasons for the lower leachate production rate at Site C.

Figure 5 is a graphical presentation of the volume of water collected in each site's secondary leachate collection system. The data collected from Site A show that earlier volumes (April 1991 through August 1991) were higher than more recent data. This likely reflects the time lag required to drain excess moisture accumulated in the sand secondary collection layer during construction. Also, construction was completed late in the year, and it is likely that the entire liner and secondary collection system were frozen shortly after construction was completed. As these layers thawed, additional water reached the collection system.

Similar initial peaks in the volume of water collected in the secondary collection systems were observed at Sites

I. Site A — Leachate volume data

Month/yr.	Precip., mm	Precip. vol., L/ha/day	Primary leachate vol., L/ha/day	Primary leachate vol., % of precip.	Secondary leachate vol., L/ha/day
Apr. 91	97	32,307	43,291	134	13
May 91	195	62,852	33,999	54	27
Jun. 91	66	21,982	18,023	82	20
Jul. 91	142	45,769	20,903	46	15
Aug. 91	26	8,380	7,620	91	12
Sep. 91	55	18,319	10,620	58	7
Oct. 91	133	42,869	7,251	17	5
Nov. 91	114	37,969	35,113	92	[b]
Dec. 91	29	9,347	12,458	133	7
Jan. 92	N/A[a]	N/A	2,769	N/A	3
Feb. 92	25	8,614	851	10	2
Mar. 92	44	14,182	34,382	242	31
Apr. 92	45	14,988	36,410	243	3
May 92	60	19,339	26,061	135	4
Jun. 92	43	14,322	17,485	122	5
Jul. 92	75	24,174	26,738	111	4
Aug. 92	N/A	N/A	24,255	N/A	4
Avg.	77	25,028	21,072	105	10

[a]N/A = Data not available
[b] = Pump malfunction mid Oct. 91 to mid Dec. 91
Cell usage began March 1992

II. Site B — Leachate volume data

Month/yr.	Precip., mm	Precip. vol., L/ha/day	Primary leachate vol., L/ha/day	Primary leachate vol., % of precip.	Secondary leachate vol., L/ha/day
Nov. 91	187	62,326	39,676	64	19
Dec. 91	30	9,676	9,280	96	24
Jan. 92	N/A[a]	N/A	4,537	N/A	7
Feb. 92	16	5,517	2,535	46	3
Mar. 92	46	14,837	35,924	242	14
Apr. 92	76	25,330	24,825	98	17
May 92	46	14,837	5,332	36	15
Jun. 92	70	23,331	4,567	20	9
Jul. 92	143	46,123	17,182	37	8
Aug. 92	N/A	N/A	2,131	N/A	2
Sept. 17,92	N/A	N/A	14,348	N/A	3
Avg.	77	25,247	14,576	80	11

[a]N/A = Data not available
Cell usage began November 1991

B and C. The highest secondary volume peak was observed at Site C, where initial system pumping and initial waste disposal coincided with the February and March 1992 spring thaw.

Figure 5 shows that the volume from the secondary collection system at each site decreased following the initial peaks. The average secondary leachate volumes recorded in Tables I–III are somewhat skewed because of these initial peaks. Initial review of the data for Site A suggests this peak may reappear each spring. However, the peak shown for March 1992 was caused by running the pump for three consecutive days in order to purge the system prior to the spring sampling event. Thus, the March 1992 peak shown for Site A is anomalous because the reported secondary collection system volume was calculated based on the pump running time and pumping rate, even though the pump was likely not removing water during the entire time.

Tables I–III show that the average leachate volume collected in the secondary collection systems for the three sites ranged from 10 L/ha/day (1.07 gal/acre/day) at Site A to 21 L/ha/day (2.24 gal/acre/day) at Site C. These data seem reasonable. Assuming each primary liner is performing equally, the composite secondary liner at Site C is less likely to allow exfiltration than the HDPE secondary liners at Sites A and B.

If the initial peak volumes recorded in the secondary collection systems at each site are eliminated from consideration, the expected long-term volumes collected in the secondary systems are much lower. Stabilized volumes in the secondary collection systems for the three landfills are presented in **Table IV**.

Conclusions

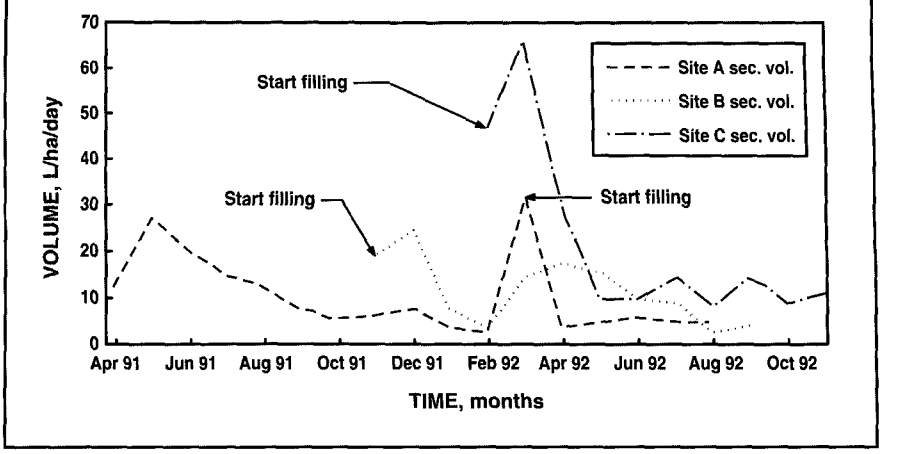
Leachate generation data were collected from three recently constructed operating landfill facilities. Each facility contains a single 1.5-mm (60 mil) HDPE primary liner. Two of the sites have single 1.5-mm (60 mil) HDPE secondary liners, and the third site has a composite secondary liner, with 1.5-mm (60 mil) HDPE directly on a 15.24-cm (6 in.) thick layer of bentonite-enriched soil having a hydraulic conductivity less than 1×10^{-7} cm/s. Construction quality control/construction quality assurance (CQC/CQA) procedures at each site were similar. Leachate volumes removed from the landfills ranged from as high as 84% to as little as 31% of the precipitation volume.

The average volume of water col-

IV: Stabilized secondary collection volume

Site	L/ha/day	gal/acre/day
A	7	0.75
B	9	0.96
C	10	1.07

5. Volumes from secondary collection systems, April 1991 through November 1992



lected in the secondary leachate collection systems at the three sites ranged from 21 L/ha/day (2.24 gal/acre/day) at Site C to 10 L/ha/day (1.07 gal/acre/day) at Site A. If the initial startup peaks in the volumes collected in the secondary systems are discounted, the calculated leakage rates for the primary liner range from 10 L/ha/day (1.07 gal/acre/day) at Site C to 7 L/ha/day (0.75 gal/acre/day) at Site A.

Data from these three synthetically lined landfills compare favorably with similar data collected from three clay-lined facilities, where liquid volumes collected in lysimeters beneath the clay liners averaged 0.094 m^3/ha/day (10 gal/acre/day) (*3*).

While this study suggests that synthetic liners may be superior to clay liners in preventing landfill leakage, it should be pointed out that rigorous CQC/CQA programs were carried out at each site by experienced field personnel. We suggest that the potential risk of environmental impact from an improperly constructed synthetic liner may actually be higher than for a clay liner. Additional safety factors inherent with clay liners include the use of several thin layers in their construction, and the leachate attenuation advantages they offer. TJ

III. Site C — Leachate volume data

Month/yr.	Precip., mm	Precip. vol., L/ha/day)	Primary leachate vol., L/ha/day	Primary leachate vol., % of precip.	Secondary leachate vol., L/ha/day
Apr. 91			10,075		
May 91			5,932		
Jun. 91			5,066		
Jul. 91	149	48,055	5,658	12	
Aug. 91	21	6,773	6,294	93	
Sep. 91	79	26,328	4,135	16	
Oct. 91	120	38,702	5,811	15	
Nov. 91	149	49,657	6,396	13	
Dec. 91	38	12,256	7,327	60	
Jan. 92	33	10,643	4,233	40	
Feb. 92	68	23,444	2,201	9	46
Mar. 92	65	20,964	10,589	51	66
Apr. 92	54	17.997	19,170	107	29
May 92	45	14,513	7,584	52	9
Jun. 92	15	4,999	4,927	99	9
Jul 92	44	14,191	8,008	56	14
Aug. 92	N/A[a]	N/A	5,271	N/A	7
Sept. 92	N/A	N/A	5,185	N/A	14
Oct. 92	N/A	N/A	6,407	N/A	8
Nov. 92	N/A	N/A	8,960	N/A	10
Avg.	68	22,194	6,961	48	21

[a]N/A = Data not available
Cell usage began February 1992

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