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Project Summary

Landfill Leachate Clogging of Geotextile (and Soil) Filters

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The primary leachate collection system of most solid waste landfills contains a filter layer which has historically been a granular soil. Recently, however, various types of geotextile filters (both woven and nonwoven) have been used to replace the natural soil filters. A project using six different landfill leachates and aimed at investigating the functioning of different geotextile filters was the focus of this 36-mo long study.

In the initial 12-mo, referred to as Phase I, flow rates in various filters were investigated under aerobic conditions at six different landfill sites with the use of the site-specific leachates. The study inadvertently found that the overlying granular soil clogged as much as the geotextile filter that was located downstream. The effects of different types and styles of geotextiles were generally masked by the upstream soil clogging. A separate anaerobic incubation task under no-flow conditions showed clogging to be present but to a significantly lesser extent than occurred with the aerobic flow tests. This clogging was believed to be completely biological in nature rather than a combination of sediment and biological processes. An important finding in this task was that biodegradation of the geotextiles was not evidenced and was concluded to be a non-issue.

The subsequent 24-mo study, referred to as Phase II(a), led to the development of a vastly improved flow rate monitoring device. With the use of these new flow columns, which are made from PVC fittings, locally available at hardware stores and very inexpensive, a wide range of variables were evaluated: i.e., four different styles of geotextiles, geotextile alone versus sand/geotextile filters, anaerobic versus aerobic conditions, and six different landfill leachates. The resulting 96 columns (4 x 2 x 2 x 6) were evaluated for their flow rate behavior over time and found to essentially replicate the first year's aerobic test results. Varying degrees of clogging by sediment or particulates and microorganisms did occur for the various geotextile and natural soil filters that were evaluated. After establishing this point, a series of backflush remediation attempts were evaluated. In general, flow rates were partially restored, but only temporarily.

In a separate task, referred to as Phase II(b) and conducted simultaneously with Phase II(a), biocide-treated geosynthetics were used at the two sites with the most aggressive leachates. Although the biocides may have been effective in killing microorganisms, the dead bacteria were as troublesome as the viable bacteria in creating subsequent clogging.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The primary leachate collection and removal systems at solid waste landfills are generally overlain by a filter layer consisting of a geotextile or a natural soil. Such filters must serve the dual tasks of allowing the leachate to pass into the underlying drain while retaining the upstream particulate matter without excessive clogging. This represents a severe challenge to the filter since many leachates contain large amounts of suspended solids and/or microorganisms.

To investigate the behavior of several geotextile filters and of an Ottawa-sand soil filter, six landfill leachates were evaluated under different experimental conditions. The characteristics of the leachate are shown in Table 1. Note that all of the sediment and microorganisms contained in the six leachates fall into a relatively tight particle size distribution entirely within the silt-size classification, i.e., they range from 0.074 mm down to 0.002 mm.

Phase I - Initial Flow Rate Evaluations

This phase of the project, which lasted for 12 mo, used flow boxes for aerobic evaluation and large containers for anaerobic incubation with subsequent testing.

In the *aerobic portion of the study*, 12 in. x 12 in. wooden flow boxes, 24 in. high were used. The boxes were all constructed using a base plate, a geonet drain, a geotextile filter, and 6 in. of free draining sand. The remaining 18 in. of the boxes were empty so that falling head permeability tests could be conducted. Leachate passed through the sand and geotextile and then flowed within the geonet, which was open at one end only. The time of flight for given quantities of leachate to pass through the system was measured. Each of the six sites had at least four boxes, the only difference being the type of geotextile filter. Both woven and nonwoven geotextiles were evaluated. They consisted of various polymer types and manufacturing styles.

The following findings are based on the flow rate behavior over the 12-mo evaluation period at each site.

(a) The flow rate measurements from the original values all decreased but varied considerably.
(b) The relatively tightly woven geotextile filter, with a 4% open area, performed the poorest. For each of the four different sites in which it was used, it clogged beyond our detection limit. The time periods were from 4-1/2 to 12 mo.
(c) Opening up the void space of the same type of woven geotextile to a 10% open area helped considerably. Flow rates still decreased but were more in line with the needle-punched nonwoven geotextile types.
(d) The needle-punched, nonwoven geotextiles performed equivalently. They were similarly constructed but were of different polymer types. The results indicate that polypropylene, polyester, and polyethylene fibers do not appear to give significantly different values in their flow rate response behavior.
(e) A heat-bonded, nonwoven geotextile was used at two sites. Its response was somewhat poorer than that of the needle-punched nonwovens but better than that of the 4% open-area woven geotextile.
(f) The Phase I study indicates that use of open-woven geotextiles and each of the needle-punched, nonwoven geotextiles resulted in equilibrium flow conditions lasting between 6 and 12 mo. The flow rate was reduced from as little as 20% of the original values (at four sites) to as much as 80% (at two sites). These reductions appeared to be related to the strength of the leachate insofar as their total solids (TS) and microorganism content (BOD) were concerned. In the worst cases, flow rates were usually greater than 1.0 gal/min-sq ft. This is equivalent to 6.2×10^7 gal/acre-day, which probably far exceeds most design requirements for leachate collection system filters.
(g) The cause of the flow reductions created somewhat of a dilemma. By cutting a cross section of the boxes at the end of the 12-mo period it was clearly evident that the 6 in. of sand over the geotextile was a major source of the flow reduction. *Clearly, the experiments showed that soil clogging is every bit as serious as geotextile clogging.* Furthermore, the soil used was a very open-graded, rounded sand (it was Ottawa sand) having a permeability coefficient of approximately 0.02 cm/sec (0.04 ft/min). Thus, it actually meets, and even exceeds, most regulatory criteria for a drainage soil, let alone for a filter soil.
(h) Microscopic examination of the cross sectioned soil/geotextile systems showed heavy particulate clogging in the upper half of the soil layer. Thereafter, the clogging was either fibrous or consisted of very small clusters. Although not conclusively proven, we believed that the upper portion of the soil column filtered the suspended solids out of the leachate and thereafter biological activity spread throughout the remaining portion of the soil column and into the underlying geotextile. This biological activity took numerous forms including the deposition of precipitates in the soil and in geotextile voids. Thus, different geotextiles (all other things being equal) responded differently to the same site's leachate.
(i) The relative amounts of flow rate reduction between leachate sediment, biological precipitates, and biological growth could not be distinguished in these particular tests.

The *anaerobic portion of the study* was performed under completely submerged conditions in 55 gal drums. Twelve samples of each type of geotextile were suspended on stainless steel racks and placed in the various sites' leachate. One sample of each type was removed for testing each month. Four geotextile types were evaluated for each of the six landfill leachates. After the samples were removed, they were brought to our laboratory and were tested for their retained flow capability and possible strength reduction. The general findings follow:

(a) *Relatively minor flow reductions occurred in all types of geotextiles evaluated.* The reduction values varied from 10% to 20%. Note that these amounts are distinctly less than those that occurred in most of the aerobic tests. We believed that sediment clogging did not form since flow was not occurring during the incubation periods. Furthermore, the absence of a soil column had a dramatic (but quantitatively unknown) effect on improving the flow rates.
(b) All of the exhumed geotextiles had heavy biological growth that could be easily seen and felt.
(c) Very informative scanning electron micrographs taken at various times of incubation were compared with the as-received geotextiles. After 3 mo of incubation, complete growth around the individual fibers or growth in clusters could generally be seen (Figure 1). Although difficult to quantify, the amount of growth was clearly related to the time of immersion.
(d) The micrographs also revealed that the biological growth was easily removed from the fiber's surface. There appeared to be no fixity or attachment to the fibers.
(e) The above observation was corroborated by various strength tests performed on the geotextiles after immersion. Within the limits of our testing, there was no strength reduction over the 12-mo period. *This suggests that for these leachates, biological degradation of geotextiles is not a problem.* Phase II studies did not include the polymer degradation issue.

Phase II(a) - Improved Flow Rate Columns and Remediation Attempts

This phase of the project, which lasted 24-mo, used vastly improved flow rate measuring systems. This type of improved system has been developed into a test method and procedure adopted by the American

Table 1. *Details of Municipal Landfill Leachates Evaluated in this Study and Approximate Leachate Characteristics*

Site Designation	Approximate Leachate Characteristics at Start-Up			
	pH	COD*(mg/L)	TS(mg/L)	BOD_5 (mg/L)
PA-1	8.0	15,000	8,000	2,000
NY-2	5.5	20,000	8,000	5,000
DE-3	5.8	40,000	17,000	24,000
NJ-4	7.4	45,000	16,000	25,000
MD-5	6.8	1,000	100	150
PA-6	6.5	10,000	5,000	2,500

**COD = chemical oxygen demand; TS = total solids content; and BOD_5 = biochemical oxygen demand at five days.*

Figure 1. *Scanning electron micrograph of geotextile fiber after 3 mo immersion in leachate from Site NY-4 (400X).*

Society for Testing and Materials as a Standard Test Method (ASTM D1987-91, "Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters"). The flow rate measuring column appears as shown in Figure 2 for evaluations being performed in a variable or falling head test mode.

Ninety-six of these devices were used under the following set of conditions:

- four different geotextiles,
- without soil and with Ottawa sand above,
- aerobic and anaerobic conditions, and
- six landfill leachates.

Continuous flow rate testing was monitored for 6-mo. Once trends were established, a series of remediation procedures were attempted.

The following comments apply to the first 6-mo of flow testing, i.e., before the first remediation was attempted.

(a) The columns with sand above the geotextiles clogged considerably more than those with the geotextile alone, i.e., 23% flow was retained for sand/geotextiles versus 34% flow retained for geotextiles alone. Note that if the heat-bonded nonwoven fabrics are eliminated from the geotextile group, the flow rate retained by the geotextile group would be 45%. This suggests that geotextiles can clog less than natural soil filters.

(b) Of the four geotextiles evaluated, the highest retained flow was achieved with the lightweight needled nonwoven (38%), with the heavyweight needled nonwoven (34%), and woven monofilament (32%) slightly behind. The nonwoven heat-bonded fabric had the lowest retained flow of only 10% after 6 mo of evaluation.

(c) Of the various landfill leachate types, the lowest retained flow rate resulted from use of the NJ-4 (14%) and DE-3 (17%) leachates. Recall from Table 1 that these are the leachates with the highest TS and BOD concentrations. The other four landfill leachates and their percentages of flow retained after 6 mo of testing were PA-6 (26%), MD-5 (29%), PA-1 (38%), and NY-2 (41%).

After the initial 6 mo of flow rate testing confirmed the results of the Phase I study, remediation of flow columns was attempted. The first remediation, a leachate backflush, improved flow rate but to varying amounts between the different columns. After 4 mo of continued flow testing, the flow rates decreased and allowed for a second remediation. This remediation used a water backflush. Again flow rates increased, but over the next 5 mo they again decreased.

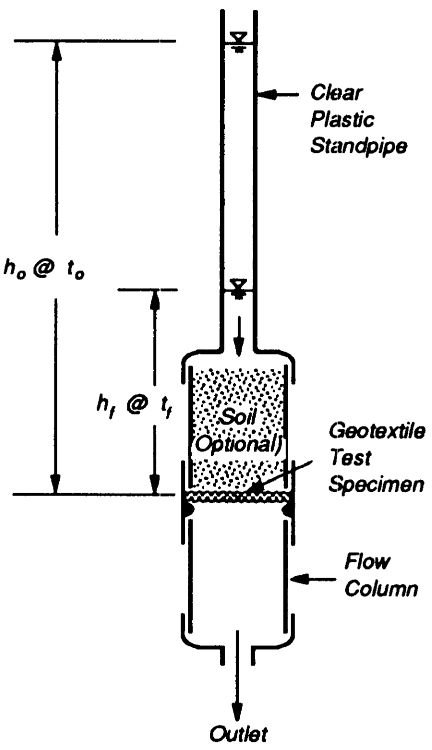

***Figure 2.** Flow rate columns used in Phase II(a) and (b) studies.*

The third remediation utilized a nitrogen gas backflush. It improved flow rates, but 3 mo later they were once again reduced. The fourth, and last, remediation was vacuum extraction, which only nominally improved flow rates when it was performed. Thereafter, the flow rate again decreased. The overall average behavior of the 96 columns is shown in Figure 3. It visually describes the decreasing flow rate trends between remediations and the rapid increase in flow rates immediately following remediation. The individual curves for each of the 96 columns are given in the full report.

To quantitatively assess the overall performance of the remediation attempts and their relative performances in contrast to one another, the data were analyzed with respect to their percent of flow rate improvement. Within each combination, however, there were decided differences. For example:

(a) Backflushing of geotextiles by themselves was more efficient than backflushing of geotextile/sand systems. The average recovery efficiencies were 29% and 13%, respectively.

(b) With sand overlying a geotextile there was no measurable difference from one type of geotextile to another.

(c) With only a geotextile, remediation was most effective with the woven, monofilament geotextiles (38% recovery efficiency), slightly less effective with the nonwoven, needled lightweight (31%) and the heavyweight (30%) geotextiles, and relatively ineffective with the nonwoven, heat-bonded geotextiles (16%).

(d) When sand is placed over the geotextile, there is no difference between anaerobic and aerobic remediation schemes.

(e) With only a geotextile, remediation was slightly better under anaerobic conditions than with aerobic conditions.

(f) When sand is placed over the geotextile, the remediation recovery efficiency rankings were: water > nitrogen > leachate > vacuum

(g) With only a geotextile, the remediation recovery efficiency rankings were: water > leachate > nitrogen > vacuum

Phase II(b) - Biocide Treated Geosynthetics

Because of the relatively large flow rate decreases observed in the course of this study, an attempt at using biocides in the flow system was undertaken. This was done under the assumption that the biocide would kill the microorganisms that come into contact with it and that the nonviable (i.e., dead) matter would pass through the system in much the same way that fine particles or sediment moves through any other filtration/drainage system. Because we believed the biocide should be introduced on a long-term basis rather than as one bulk dose, the biocide was added to the polymer compound during fabrication of the selected geonets or geotextiles. The reasoning was that the biocide would release over time (via molecular diffusion) through the polymer structure and migrate to the surface of the ribs or fibers over a long period of time.

From the results of these biocide treated geosynthetics, we believe the location of the biocide vis-a-vis the initial formation of a biofilm layer was critical. This was confirmed at the end of the tests after solidifying the test columns with epoxy and cutting them apart. Clearly, the biofilm layer was occurring at the top of the sand column some 2 to 3 in. above the biocide-treated geosynthetics. Although there may have been some flow rate improvement due to high concentrations of biocide, it was very subtle (at best) and was masked by the inherent scatter in the test data. There was essentially no difference between flow rates in anaerobic versus aerobic conditions.

These findings led to additional tests without sand above the biocide-treated geosynthetic that forced the leachate to interface directly with the biocide. Rather than use a single type of geotextile, three different types were utilized. The opening sizes varied from 0.15 mm (nonwoven, needle-punched style), to 0.21 mm (a woven monofilament), to 0.42 mm (another woven monofilament). Quite clearly, the flow rates through the largest opening size geotextiles, i.e. the 0.42 mm, were the highest. This suggests that microorganisms (dead or alive) must be able to pass through the system. Whenever these microorganisms reside on or within the small pores of the filter, partial, or even complete, clogging is possible.

Conclusions

A simulated field-oriented project concerning biological clogging of landfill drainage systems was focused on geotextile filter clogging. A number of domestic landfill leachates were employed. The filter was singled out (versus the geonet drain, drainage stone or perforated pipe) since it has the smallest openings and is likely to become clogged before other components. Geotextiles were emphasized because they are relatively new materials for this particular application.

Phase I results reoriented our initial goals since the granular soils covering the filters were clogging before the geotextiles were. Furthermore, sediment and/or particulates were a major factor in flow rate reductions, which appeared to be synergistic with the biological clogging. Clearly, partial filter clogging was occurring with a gradual reduction of flow rate over time. These trends were common to all six landfill leachates being used. All of the landfills were domestic (Subtitle "D") facilities; but their waste stream, volume of waste deposited, and liquid management schemes differed. We recognized early in this Phase I activity that remediation attempts would be a necessary part of the overall study, but the Phase I experimental setup could not accommodate such activities. New and different test devices would be needed if such attempts were to be made. We did, however, draw the following conclusions from Phase I activities.

- Filter clogging (as indicated by flow rate reductions) over the 12-mo test period varied widely, the range being between 10% and complete (i.e., to the limit of our testing capability).
- A geotextile filter must be relatively open in its pore structure if it is to limit the amount of clogging, i.e., the geotextile must be capable of passing the sediment or particulates along with the associated microorganisms into the down-gradient drainage system.
- The polymer type (polypropylene, polyester or polyethylene) comprising the geotextile fibers appears to be a nonissue.

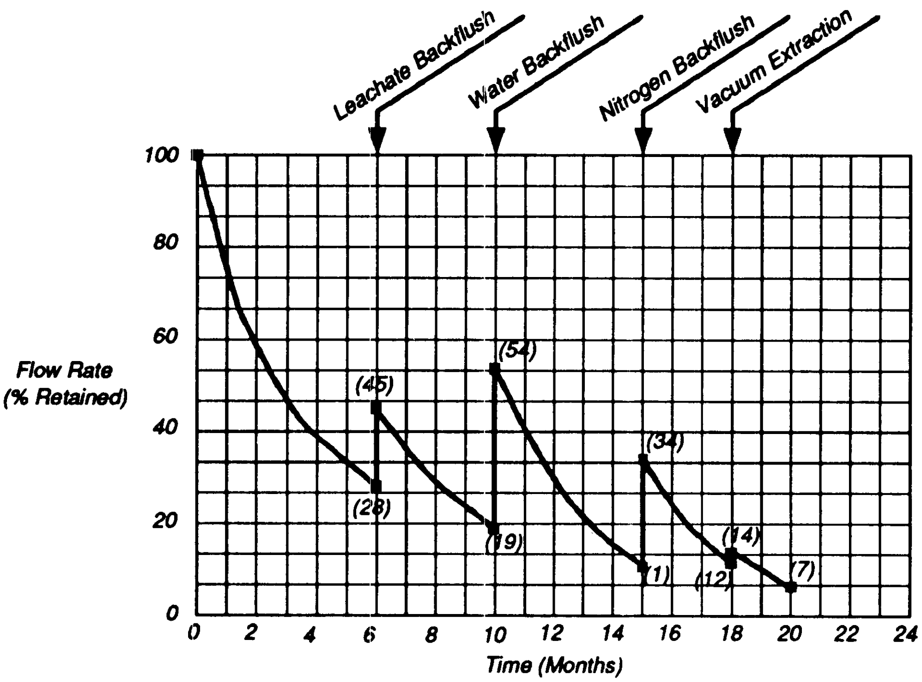

Figure 3. Average response of 96 flow rate columns from Phase II(a) activities.

- Both anaerobic and aerobic conditions promote clogging; the relative amounts, however, were not capable of being identified because of differing test setups.
- The strength of the geotextiles was not adversely affected by the 12-mo exposure to the various leachates. This finding, coupled with numerous micrographs which showed no chemical attachment of bacteria to the fibers, led us to conclude that *biological degradation of polymeric based geotextiles does not occur.*

Phase II(a) of the study saw the development of a new and vastly improved test device for flow rate evaluation. The 4-in.-diameter flow columns developed during this project have the following capabilities.

- All types of cross sections can be evaluated: geotextiles by themselves, soil/geotextile systems, soil/geotextile/geonet systems, or soil/geotextile/gravel systems.
- Anaerobic or aerobic conditions can be maintained.
- Flow rates can be evaluated using falling head or constant head measurements.
- The devices are relatively small and quite portable. Therefore, they can be stored indoors and taken to a site for evaluation, or stored at the site, or even stored within the leachate storage tank or sump.
- Various methods for remediation of clogged systems can be evaluated.
- The test devices and their measurement protocol have recently been adopted as an ASTM Test Method under the designation of D1987-91.
- The test devices and their contents can be solidified by epoxy and cut in half to visually observe the conditions existing within the cross section.
- Since all parts of the device consist of PVC plumbing and swimming pool accessories, they are readily available, easily sealed by chemical wipes, and inexpensive.

The following conclusions were reached from this Phase II(a) study.

- Flow rate reductions were similar to the results of Phase I, and the conclusions drawn earlier have been substantiated.
- If geotextile and/or soil filters are to be used in leachate collection systems, they should have sufficiently open voids to pass the sediment or particulates along with the microorganisms contained in the leachate into the downstream drainage system.
- The limiting or equilibrium flow rate retained must exceed the site specific design requirement. If flow rates over time are not adequate, remediation is necessary. It was found that the water backflush technique gave the best results (35% improvement), nitrogen gas backflush (23%), and leachate backflush (17%) methods were next. The vacuum extraction was the least effective; it provided only nominal improvement (2%).
- The periodicity of backflushing to open up a clogged or semi-clogged filter system appears to be approximately 6 mo.

Incorporating biocides into the geotextile (or geonet) polymer structure to keep the flow system open was Phase II(b) of the study. The concept was to add various amounts of a time-released biocide into the polymer compound as the product was manufactured — biocide that would essentially diffuse to the surface of the fibers during its service life. On contact, it would kill the viable microorganisms in the leachate. In the tests that were conducted on 16 separately built flow columns, some experimental evidence indicated that 2% and 4% biocide was partially effective. The remains of the dead bacteria must, however, be permitted to pass through the system, and this apparently could not happen for our particular tests setups. Thus, the idea of a very open filter system was further reinforced.

Recommendations

Based on the major findings of this project, namely,

- under continuous flow of landfill leachate a gradually decreasing flow rate will occur for all types of filters (soil or geotextile) and eventually reach an equilibrium value,
- the equilibrium value of flow rate will vary according to the type of filter, the type of leachate, and the hydraulic gradient, and
- the equilibrium flow rate for any given filter system must be compared with the design required flow rate to ultimately assess the adequacy of the filter's design,

we feel that the following recommendations should be considered regarding geotextile and soil filters placed over different types of leachate collection drains.

(a) Design criteria should be developed that considers the amount, size, and type of microorganisms and sediment present in the leachate along with conventional issues such as hydraulic gradient and type of filter.

(b) Leachate collection systems at landfills that are decommissioned or exhumed for other reasons should be investigated in light of the results of this study.

(c) This particular project should be followed by another effort aimed at a larger variety of geotextile filters along with design guidance and field performance of existing systems.

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The complete report, entitled "Landfill Leachate Clogging of Geotextile (and Soil) Filters," (Order No. PB91- 213 660/AS; Cost: $23.00, subject to change) will be available only from:
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