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George R. Koerner and Robert M. Koerner

BIOLOGICAL ACTIVITY AND POTENTIAL REMEDIATION INVOLVING GEOTEXTILE LANDFILL LEACHATE FILTERS

REFERENCE: Koerner, G. R. and Koerner, R. M., "Biological Activity and Potential Remediation Involving Geotextile Landfill Leachate Filters," "Geosynthetic Testing for Waste Containment Applications, ASTM STP 1081, R. M. Koerner, Ed., American Society for Testing and Materials, Philadelphia, 1990

ABSTRACT: This paper presents the results of a biological growth study in geotextile filters used in landfill leachate collection systems. After reviewing the first year's activity, a completely new experimental approach has been taken. Using 100 mm diameter columns for the experimental incubation and flow systems, the effects of six landfill leachates are evaluated. Aerobic and anaerobic states, four different geotextiles, and soil/no soil conditions above the geotextiles are involved in the testing program. This results in 96 individual test columns. Flow data is measured regularly, and over the first six months of evaluation the following trends have been observed.

- no clogging (0%-25% flow reduction)
  6 of 96 columns = 7%
- minor clogging (25%-50% flow reduction)
  4 of 96 columns = 4%
- moderate clogging (50%-75% flow reduction)
  37 of 96 columns = 38%
- major clogging (75%-95% flow reduction)
  35 of 96 columns = 36%
- severe clogging (95%-100% flow reduction)
  14 of 96 columns = 15%

For two of the landfill leachates, backflushing has been attempted so as to reinstitute flow. This procedure works well for the geotextile alone while not as well for the geotextile/soil columns. The exception is the nonwoven heat set geotextile. All tests are still ongoing and will be dismantled and further investigated at the end of 12 months exposure time. The experimental setup and procedure has been written up as a tentative ASTM test method and is currently in task group review.

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KEYWORDS: biological clogging, aerobic, anaerobic, soil clogging, geotextile clogging, filtration, leachate, bacteria count, viable count

INTRODUCTION

The leachate collection systems used above and below primary liners in landfills are meant to function in a free flowing gravitational mode for their entire active and post closure care periods. Such leachate collection systems consist of a drainage material (either sand, gravel or a geonet), a protective filter (either sand or a geotextile), and sometimes a perforated pipe covered with an appropriate filter (either sand, gravel or a geotextile). Figure 1 shows the location of these materials where geosynthetic alternates are illustrated. It should be noted that a fine grained soil (silt, clay or mixture) is frequently placed between the leachate collection system and the waste. This layer if often referred to as an "operations layer" or "working surface". Due to its small void structure it could filter out micro-organisms and fine sediment in the leachate. This condition is not modeled in the tests to be described in this paper. While both natural materials and their geosynthetic counterparts can be designed using state-of-the-art techniques and test methods, the general focus is usually on short-term performance. When periods of 30 to 50 years are required, long-term concerns must also be addressed. Obviously, durability and aging concerns are very important [1,2], but concern that the leachate collection system remains free flowing is also important. With clogging will come a buildup of hydraulic head on the filter, creating a zone of saturation within the waste. Thus long-term clogging becomes an issue since it can arise from either particulate or biological mechanisms. Particulate clogging has been evaluated in a number of test simulations, e.g. gradient ratio [3], long-term flow [4] and hydraulic conductivity ratio [5] tests. Biological clogging, however, has only recently been addressed [6] and/or evaluated [7,8]. This paper is focused toward a continuation of an earlier report on biological clogging of geotextiles and represents modifications and extensions of that initial one year effort.

OVERVIEW OF FIRST PHASE OF PROJECT

It is well recognized that municipal landfill leachates contain large amounts of various microorganisms, primarily different forms of bacteria. Figure 2 shows the biological counts at six landfills in the northeast region of the USA. The total direct count measures all bacteria, while the viable titer gives the living bacteria count in units of number of cells per milliliter of leachate. Note the magnitude of these numbers. Chemical analysis data on these same six landfill leachates are given in Table 1. It is evident from this data that each leachate is unique. The BOD_5 values are generally considered to be the best indicators of the available biological activity.

This information certainly suggests that biological activity is present and when combined with moderate-to-warm temperatures (as occurs at the bottom of a landfill) and an ample food source (as contained in domestic waste), the growth of bacteria within the

TABLE 1 -- Details of municipal landfill leachates evaluated in this study and approximate leachate characteristics after first year's study.

Site Designation	Leachate Management Scheme	Approximate Leachate Characteristics at Project Startup			
		pH	COD (mg/l)	TS (mg/l)	BOD_5
PA-1	Continuously Removed	8.0	15,000	8,000	2,000
NY-2	Recycled through Landfill and Continuously Removed	5.5	12,000	7,000	3,000
DE-3	Recycled through Landfill	5.8	40,000	17,000	24,000
NJ-4	Continuously Removed	7.4	45,000	16,000	25,000
MD-5	Continuously Removed	6.8	5,000	2,000	1,000
PA-6	Continuously Removed	6.5	10,000	5,000	2,500

where

COD = chemical oxygen demand
TS = total solids content
BOD_5 = biochemical oxygen demand at five days

leachate collection systems is certainly possible. Further consideration of the situation would suggest that the filter (rather than the drain) should be the focus of attention since it contains the smallest voids through which the leachate must flow. This is the case for both fine to medium sand filters and geotextile filters since their void diameters are approximately the same, however, their thicknesses are significantly different. The point to be made is that both sand and geotextile filters should be evaluated for their biological clogging potential.

The first phase of this project [9] evaluated seven different geotextiles (a minimum of four per site) in aerobic flow boxes with sand above them, and an additional four in anaerobic incubation drums with subsequent flow and strength tests. The study was performed at six landfill sites and lasted for twelve months. From the aerobic flow tests it was found [9];

(a) that flow rate reductions were from 40% to 100%,
(b) that geotextile opening size played a key role, with larger sizes allowing for passage of the clogging sediment and/or dormant bacteria,
(c) that the type of geotextile polymer is of no great significance,
(d) that soil clogging could not be separated from geotextile clogging, and
(e) that particulate clogging could not be distinguished from biological clogging.

From the anaerobically incubated samples it was found [9];

(a) that flow rate reductions were from 10% to 40%,
(b) that the biological buildup was cumulative as confirmed by photomicrographs which showed progressively greater biological attachment over the 12 month testing period, see Figure 3,
(c) that there was no physical attachment of the biological growth to the geotextile fibers, and
(d) that there was no strength loss of the geotextile over the 12-month incubation period

Building upon these results, a second phase of the project was aimed at eliminating the objectionable features of the first phase and providing for an opportunity to remediate the filtration systems by backflushing. The results of this second phase activity follows for the remainder of the paper.

DETAILS OF CURRENT PROJECT

It is felt that, the new test columns for this second phase of the study of biological activity in landfill filters must meet the following criteria.

(a) Sand filter clogging should be distinguishable from geotextile filter clogging.
(b) Particulate clogging should be distinguishable from biological clogging.
(c) Partly saturated (aerobic) clogging should be distinguishable from saturated (anaerobic) clogging.

(d) Identical geotextiles should be used at every site.
(e) The flow columns should be capable of accommodating continuous or periodic flow testing.
(f) The flow columns should use the leachate at the time of testing and not be stored for any length of time least it change in its composition.
(g) Constant head or variable head conditions should be capable of being accommodated.
(h) The flow columns should be capable of being backflushed with leachate and the results assessed.
(i) The flow columns should be capable of being flushed from either side with biocide and the results assessed.

In order to meet these needs, flow columns as shown in Figure 4 have been developed and are used in this second phase study. It must be cautioned, however, that some owners or agencies may not allow backflushing as a remediation method.

The flow columns of Figure 4 are constructed out of commonly available 100 mm diameter PVC pipe and related fittings. The containment ring is actually a pipe coupling which has a raised inner "lip" upon which the geotextile is placed and sealed. A non-water soluble adhesive is used to bond the geotextile to the lip and to prevent edge leakage. The upper and lower tubes are both 100 mm long pieces of pipe and they are contained by end caps which have 25 mm holes pre-drilled in them and are threaded. Support gravel is placed below the geotextile prior to positioning and gluing the lower end cap. Similarly, if soil is to be placed above the geotextile it must be done before the upper end cap fixed. End cap adaptors are then threaded into the end caps and fitted with 25 mm flexible tubing (for constant head tests) or rigid tubing (for variable head tests). These two options are shown in Figures 5 and 6, respectively, along with photographs of the completed devices. The experimental design for this second phase study was as follows:

- Four identical (continuous filament) geotextiles were used at each site and under each set of conditions:
  - 240 g/m^2 woven monofilament of 0.21 mm average opening size and 6% open area
  - 140 g/m^2 nonwoven heat set of 0.21 to 0.15 mm average opening size
  - 270 g/m^2 nonwoven needle punched of 0.21 mm average opening size
  - 540 g/m^2 nonwoven needle punched of 0.15 mm average opening size
- Soil (uniformly graded Ottawa sand of 0.42 mm average size) was placed above one set of the geotextiles, while nothing was placed above another set.
- One set of all of the above mentioned columns was allowed to drain between readings (thus providing aerobic conditions), while another set was constantly immersed in leachate (thus providing essentially anaerobic conditions). Note that throughout this paper we will refer to this setup as being anaerobic due to its full saturation conditions. It is very possible, and perhaps even likely, that some small amount of air enters the system greatly complicating the actual bacterial composition.
- All of the above variations were done at each of the six landfill

sites, thus 96 (4 × 2 × 2 × 6) flow columns of the type shown in Figure 4 are included in this study.

RESULTS OF CURRENT PROJECT

This section describes the results of individual studies using the flow columns just described. The subsections to be described are, (a) continuous short term flow tests, (b) periodic long term flow results, and (c) the effects of leachate backflushing.

(a) Short-Term Continuous Flow Tests

Since all of the tests during the first year were performed on a monthly basis, and the distinction between fine particulate clogging versus biological clogging was never settled, a set of continuous flow tests were performed. Here the flow columns were set up in a variable head mode, as shown in Figure 6, and leachate was continuously supplied directly from a leachate sump and passed through the system. The geotextile/soil configuration was used so that flow times were long enough to be accurately measured. The results of this testing at the two sites with the harshest leachates, DE-3 and NJ-4, are shown in Figure 7. After an initial decrease which was probably a tuning of the soil/geotextile system to the flow regime and the formation of a stable flow network, the permeability of each leachate leveled off to essentially constant values. Thus it was felt that what sediment is in the leachate does not continue to build up so as to stop, or even substantially decrease, the system's flow. This suggests that the short term filtration characteristics of the soil and the geotextile are adequate to handle the indicated flow rates. It furthermore, provides a reference plane to which the long-term flow rates can be compared. Such long-term flow tests are the focus of the next section.

(b) Long-Term Intermittent Flow Tests

Long term flow evaluation of the columns at all six landfill sites were undertaken. Variable head tests of the sixteen variations at each site were performed for six months. Figures 8, 9, 10 and 11 give these results for each of the four geotextiles mentioned in the previous section. They are the woven, nonwoven heat-set, light nonwoven needled and heavy nonwoven needled geotextiles respectively. The anaerobic results are on the left sides of each figure and the aerobic results are on the right sides. The soil covered geotextiles are the upper curves, while the geotextiles by themselves are the lower curves for each figure. The coding on the graphs for the various test conditions is as follows.

WM(N)-PP	= woven monofilament (non-calendared) polypropylene
NW(HS)-PP	= nonwoven (heat set) polypropylene
NW(N)-PET 8 oz	= nonwoven (needled) polyester of 8 oz/yd^2 weight
NW(N)-PET 16 oz	= nonwoven (needled) polyester of 16 oz/yd^2 weight

AN/S = anaerobic condition with sand above
A/S = aerobic condition with sand above
AN/W = anaerobic condition without sand above
A/S = aerobic condition with sand above

Some observations on the trends observed in Figures 8 to 11 are worthy of note.

- The anaerobic flow behavior is remarkably similar to the aerobic flow trends insofar as the system permeability is concerned.
- The tests with sand above the geotextiles are much smoother in their trends than those of the geotextiles alone which have very abrupt changes in permeability.
- In general, the sand/geotextile systems gradually decreased in their permeability with the nonwoven heat set geotextile of Figure 9 showing the greatest decrease after six months.
- Viewing the entire set of data collectively, we find the following:
  - no clogging (0%-25% flow reduction)
    6 of 96 columns = 7%
  - minor clogging (25%-50% flow reduction)
    4 of 96 columns = 4%
  - moderate clogging (50%-75% flow reduction)
    37 of 96 columns = 38%
  - major clogging (75%-95% flow reduction)
    35 of 96 columns = 36%
  - severe clogging (95%-100% flow reduction)
    14 of 96 columns = 15%
- Within this group, the leachates of DE-3 and NJ-4 resulted in the greatest amount of clogging. They will be focused upon in the next section.

(c) Leachate Backflushing Tests

Paralleling efforts in the sewer pipe cleaning, agricultural drain cleaning and sewage treatment filter cleaning businesses, it appears worthwhile that we should attempt backflushing. Each column was backflushed using the site specific leachate at the end of its six month incubation, i.e., at the terminus of the graphs shown in Figures 8 to 11. Backflushing was done from the bottom of the geotextile at a constant head of 60 cm for a period of 15 minutes. The head was sufficiently low so as not to have liquifaction of the sand above the geotextile for those cases where the system had sand. The percent recovery determined by performing regular flow tests after the backflushing is given in Table 2. Note that in all cases the geotextile by itself was restored to a higher recovery flow rate than the sand/geotextile combinations with the exception of the nonwoven heat set geotextile. When the columns are dismantled we will examine this situation carefully.

Within the following month after this flow rate recovery, flow again was seen to decrease. These trends, however, are still being developed. We anticipate patterns such as illustrated in Figure 12. A number of features of these curves are of significance. They show the periodicity of required backflushing, how biocide introduced into the backflush affects the situation, and the net recovery reinstated after each backflushing. Work is ongoing in this regard.

TABLE 2 -- Percent flow rate recovery after leachate backflushing at 60 cm head for 15 minutes.

Biological Condition	Material Above Geotextile	Geotextile Type	Landfill Site DE-3	NJ-4
anaerobic	sand	woven monofilament	60%	50%
aerobic	sand	woven monofilament	40	40
anaerobic	no sand	woven monofilament	100	100
aerobic	no sand	woven monofilament	100	100
anaerobic	sand	nonwoven heat set	60	45
aerobic	sand	nonwoven heat set	40	40
anaerobic	no sand	nonwoven heat set	5	10
aerobic	no sand	nonwoven heat set	5	5
anaerobic	sand	light nonwoven needled	60	60
aerobic	sand	light nonwoven needled	60	40
anaerobic	no sand	light nonwoven needled	80	75
aerobic	no sand	light nonwoven needled	60	60
anaerobic	sand	heavy nonwoven needled	60	55
aerobic	sand	heavy nonwoven needled	60	40
anaerobic	no sand	heavy nonwoven needled	100	85
aerobic	no sand	heavy nonwoven needled	50	65

SUMMARY AND CONCLUSIONS

The long term drainage of leachate collection systems at landfill sites is of major importance in understanding leachate management strategies. If the filters for such drains clog (via either particulate or biological activity), the hydraulic head on the filter will increase, forcing saturated leachate conditions into the waste mass itself. The indications from the first year's study of this project, and the repetition with a greatly improved containment device over a subsequent six months, strongly suggests that such clogging and leachate buildup will occur. From the second generation flow devices presented in this paper it appears as though the majority of clogging is biologically oriented rather than particulate. The times for severe clogging (arbitrarily defined as a flow reduction of 95% or more) for the different soil/geotextile and geotextile systems are relatively short. It was seen that the geotextiles by themselves exhibited a dramatic decrease in flow soon after biological activity initiated. In contrast, the geotextile/soil systems exhibited gradual decreases in flow after biological activity initiated. We feel that the soil affords a thickness (or buffering) effect which is not available to the geotextile by itself.

In order to alleviate the clogging, leachate backflushing tests were performed on all 96 incubation devices. The improvement was remarkable: approximately 51% flow rate increase for the sand/geotextile combinations and 63% for the geotextiles by

themselves. Of course, some (or all) of the clogging may return. That is precisely the stage we are currently investigating.

In closing it should be emphasized that many different leachate collection cross sections are possible and we have examined only two of them, i.e., the geotextile by itself and geotextile with an overlying medium rounded sand layer. Different soil types, the existence of operation's layers or working surfaces, etc., will all influence the leachate flow regime and have different implications. Thus site-specific modeling of the intended cross section should be undertaken. This paper has given a experimental method and procedure to accomplish this type of modeling. Regarding the use of backflushing to relieve clogging of leachate filters it should be cautioned that the removal system must be designed accordingly and approval of this approach must be gained during the permitting process. It should also be recognized that the backflushing liquid, if water, will add to the leachate quantity to be eventually treated and is generally not desirable from an operations point of view. Thus air (or nitrogen) backflushing or vacuum withdrawal might be desirable options. Both of these possibilities are currently being evaluated.

ACKNOWLEDGEMENTS

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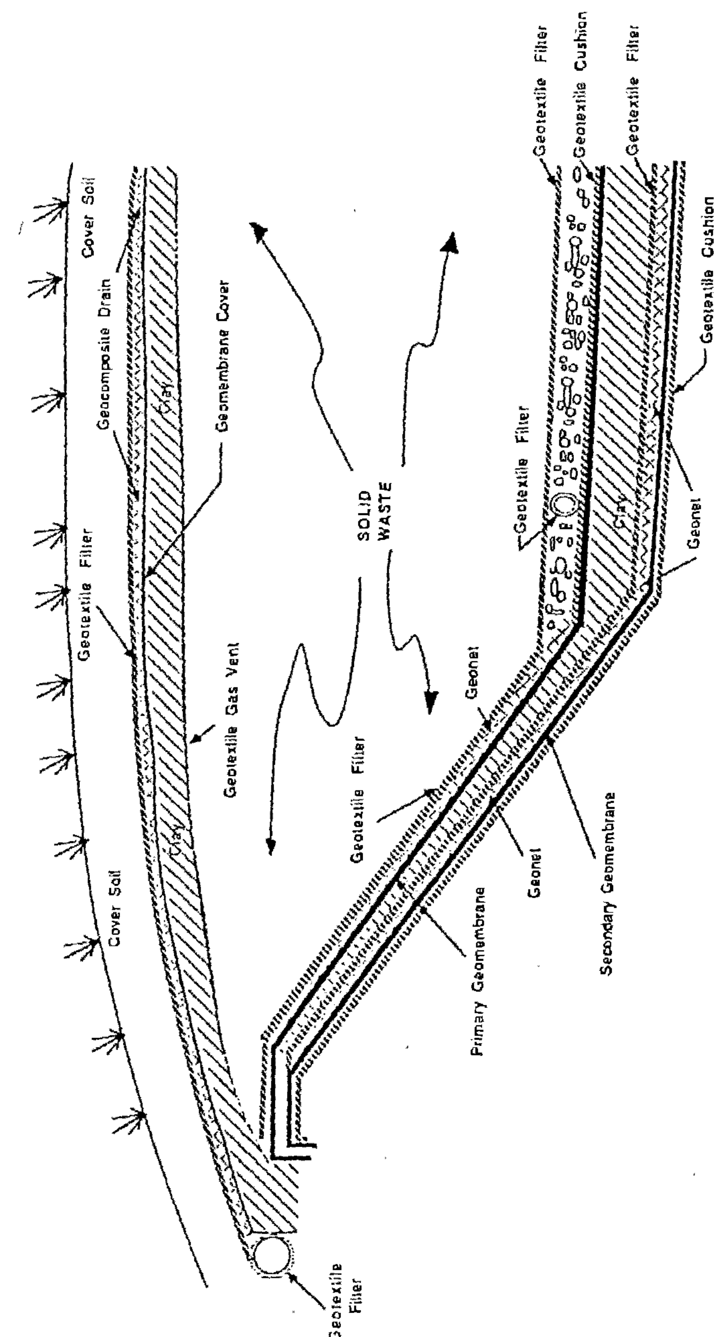
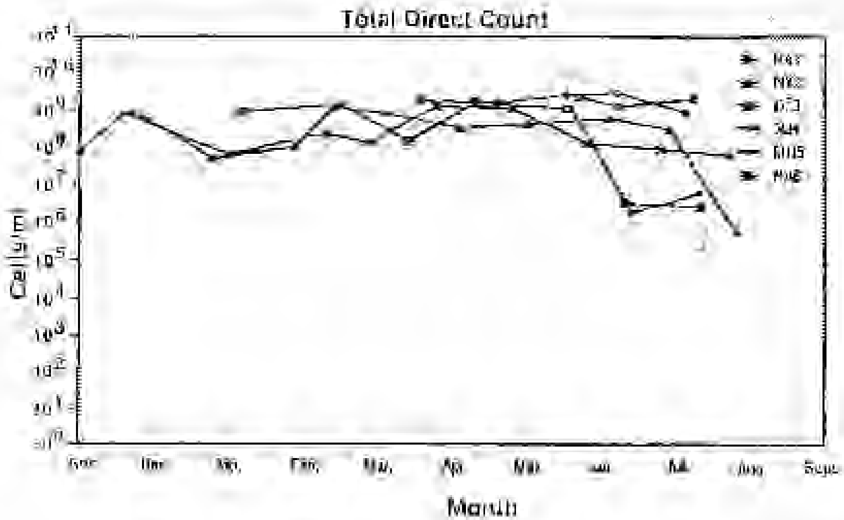




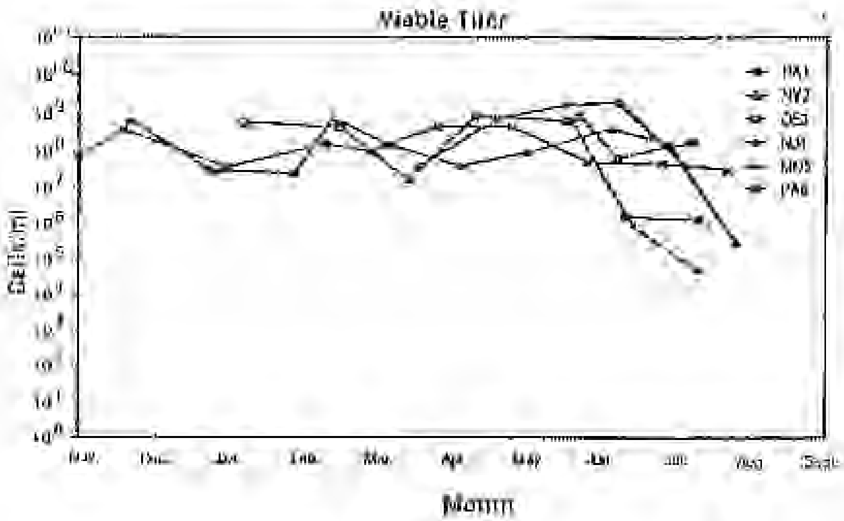
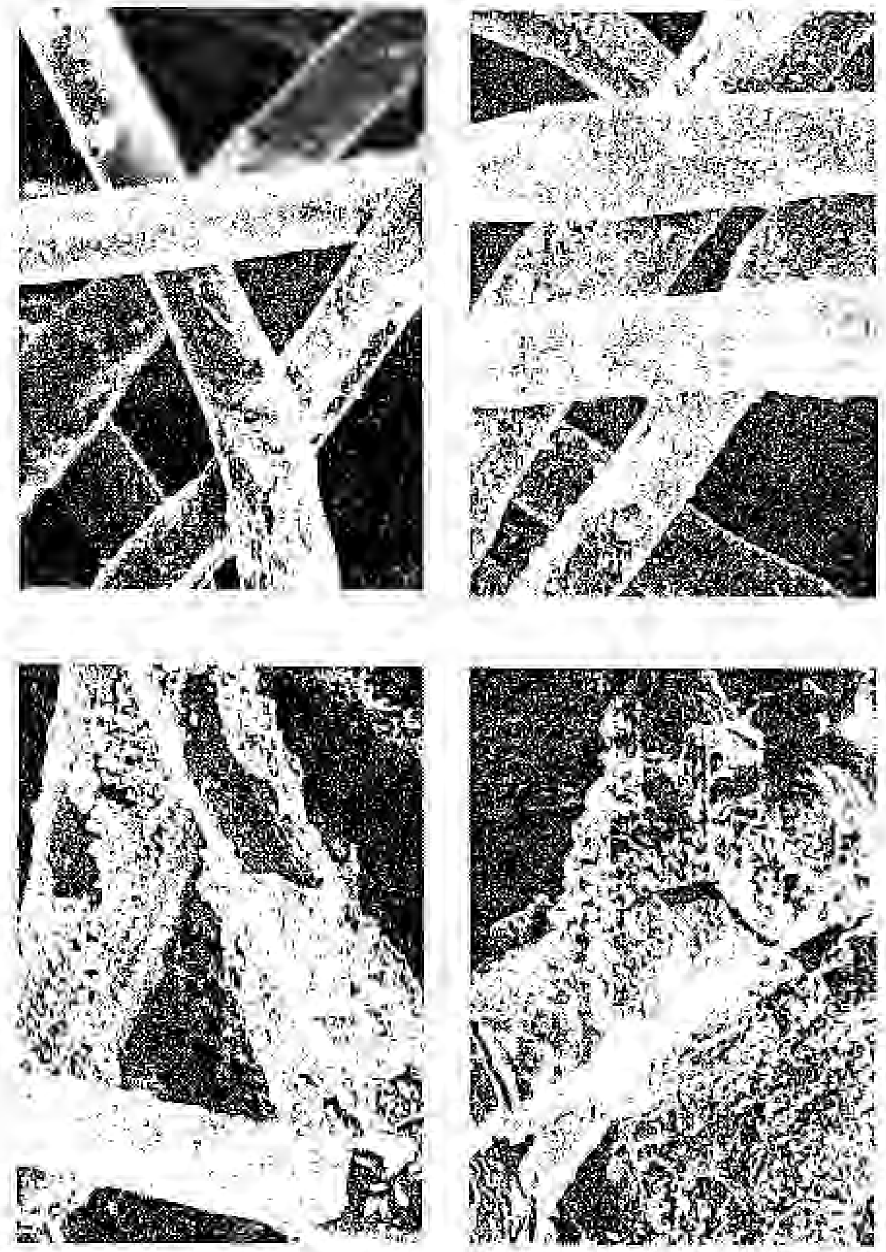


FIG. 2 -- Total bacteria count and viable (living) count of leachate samples from the six landfill sites evaluated in this study after Rigo and Geast [7].



PA1 NW(N)-PP2 400X 6M

PA1 NW(N)-PP2 400X 12M

FIG. 3 -- Scanning electron micrographs of biological growth on geotextile fibers after 1, 3, 6 and 12 month anaerobic incubation.

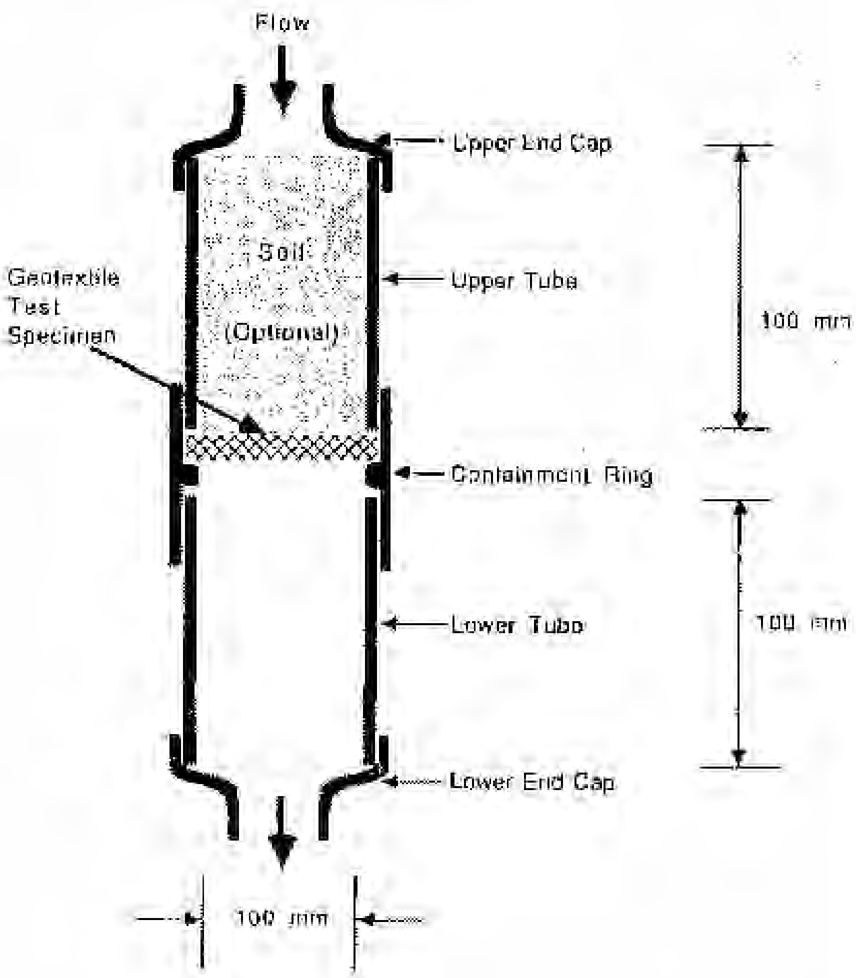


FIG. 4 -- Flow column used to contain geotextile test specimen and optional use of soil/geotextile combined systems.

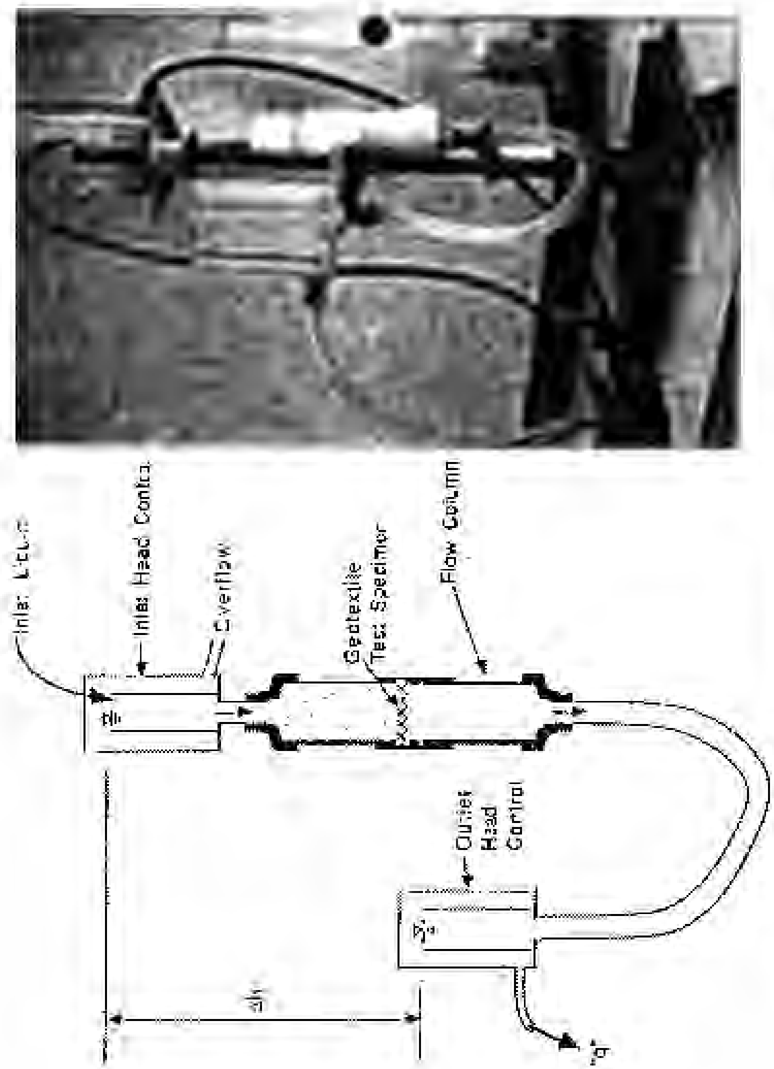


FIG. 5 -- Flow column and hydraulic head control devices for constant head tests.

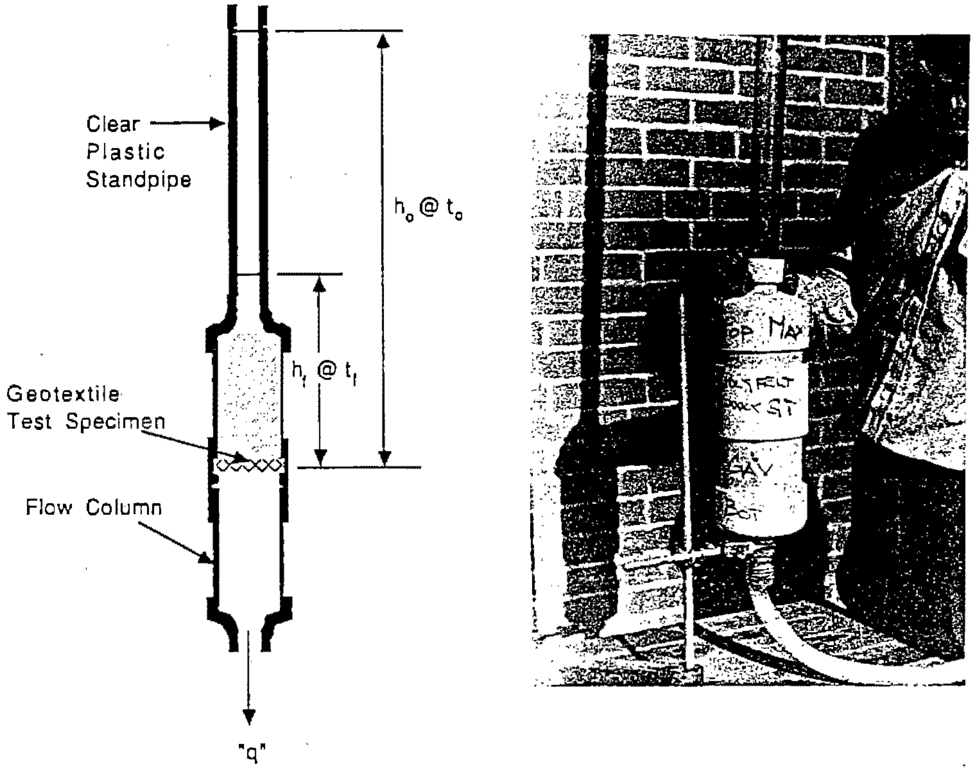


FIG. 6 -- Flow column and hydraulic head control devices for variable (or falling) head tests.

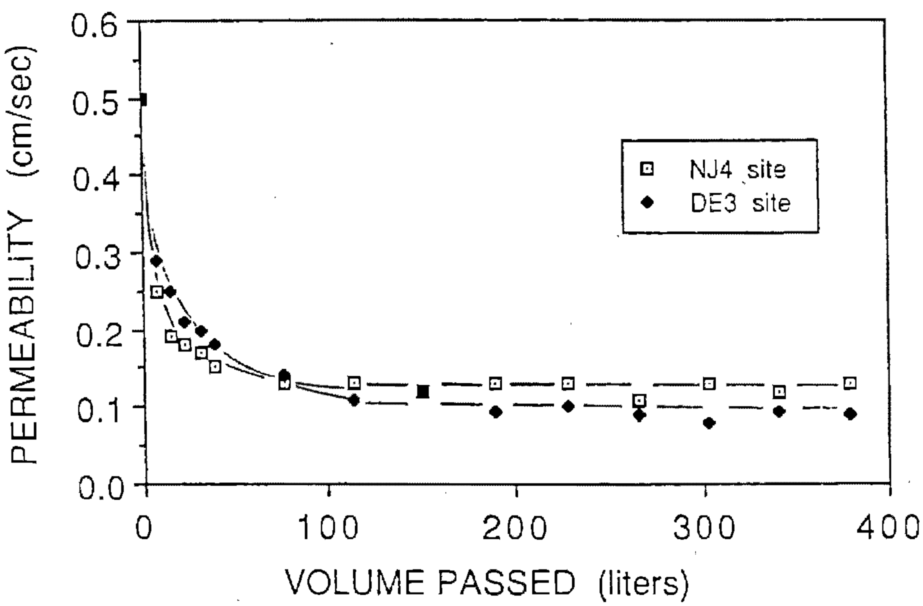


FIG. 7 -- Results of continuous leachate flow testing of soil/geotextile column at DE-3 and NJ-4 sites based on variable head tests.

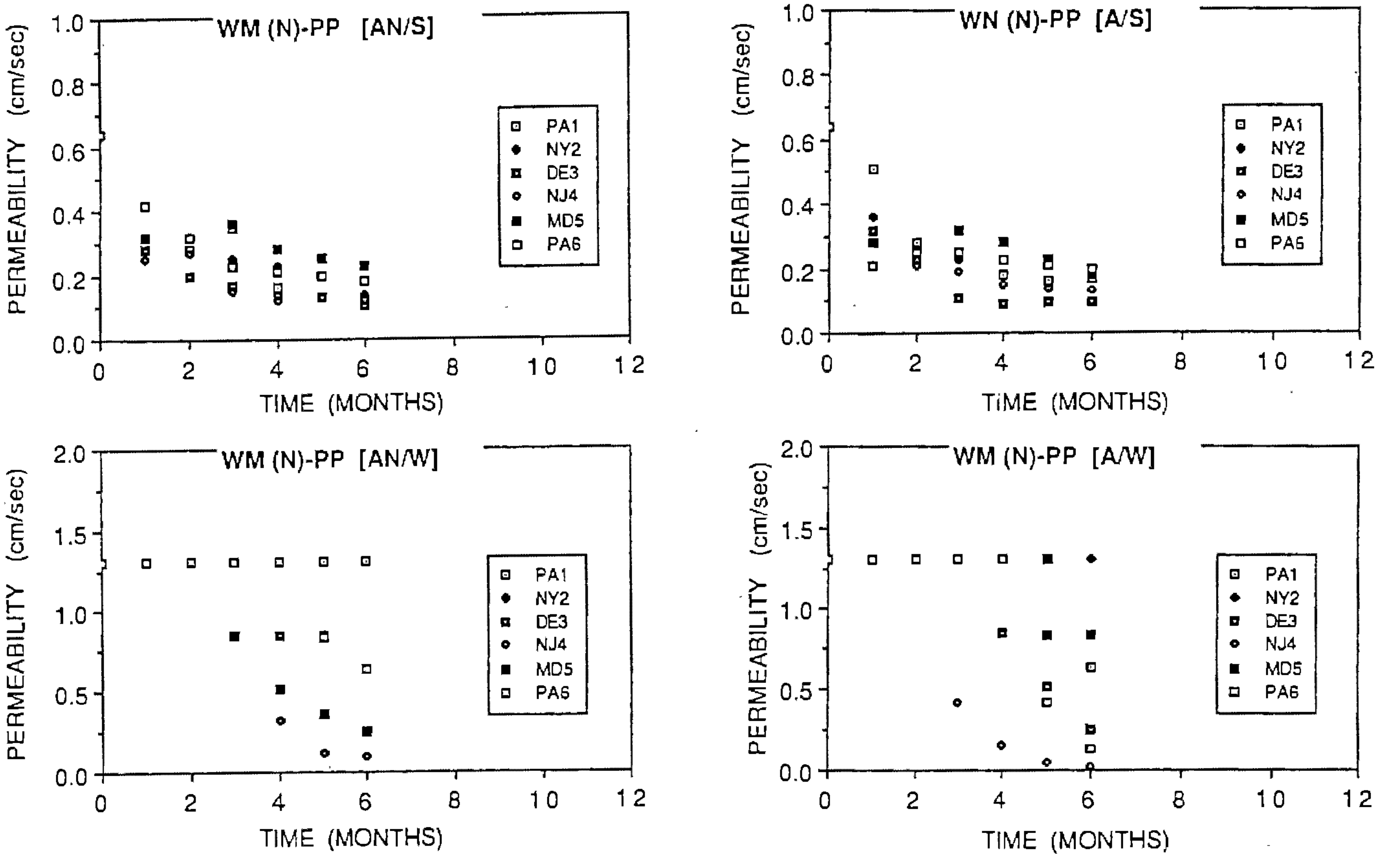


FIG. 8 -- Leachate permeability response from all six landfills under four conditions for woven monofilament geotextiles.

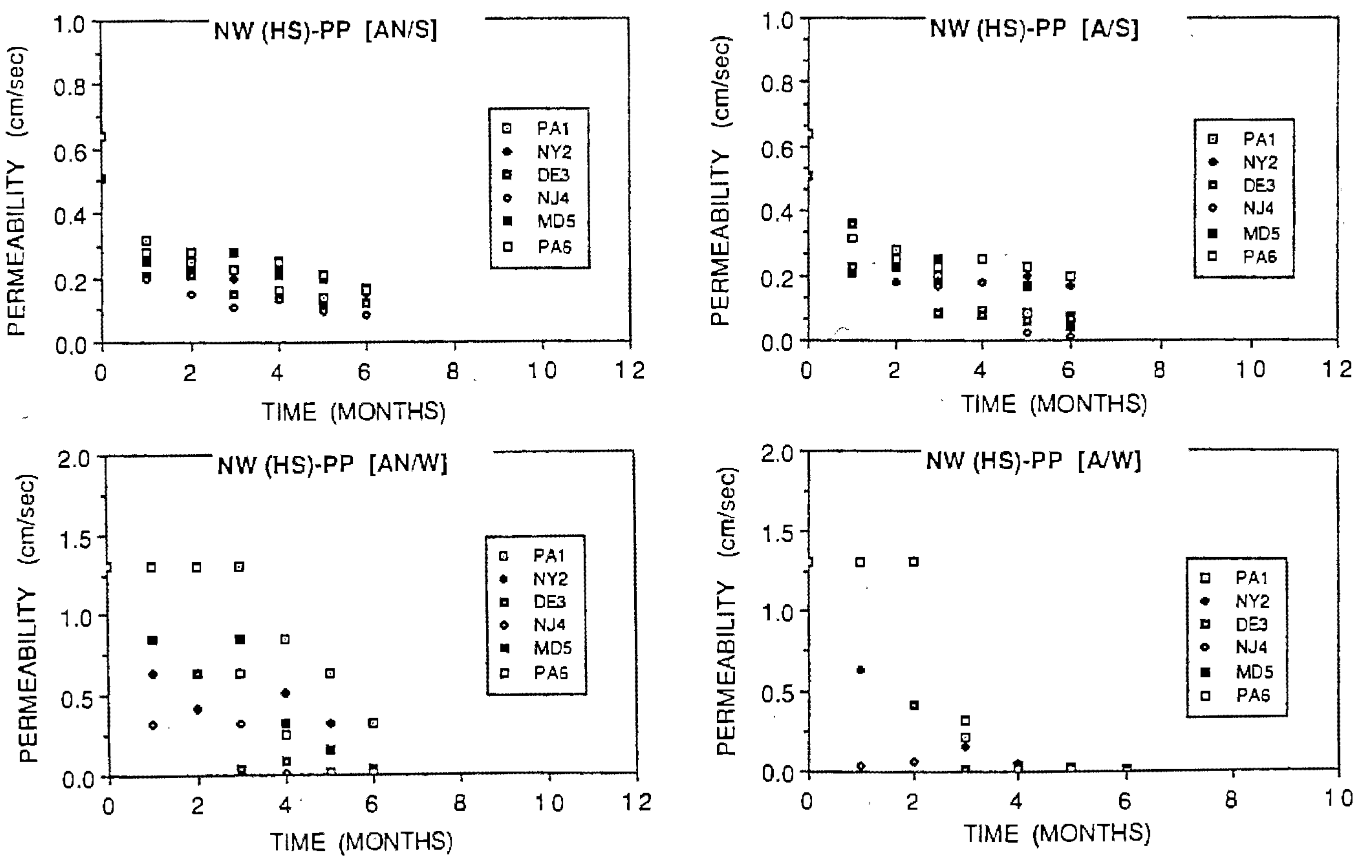


FIG. 9 -- Leachate permeability response from all six landfills under four conditions for nonwoven heat set geotextiles.

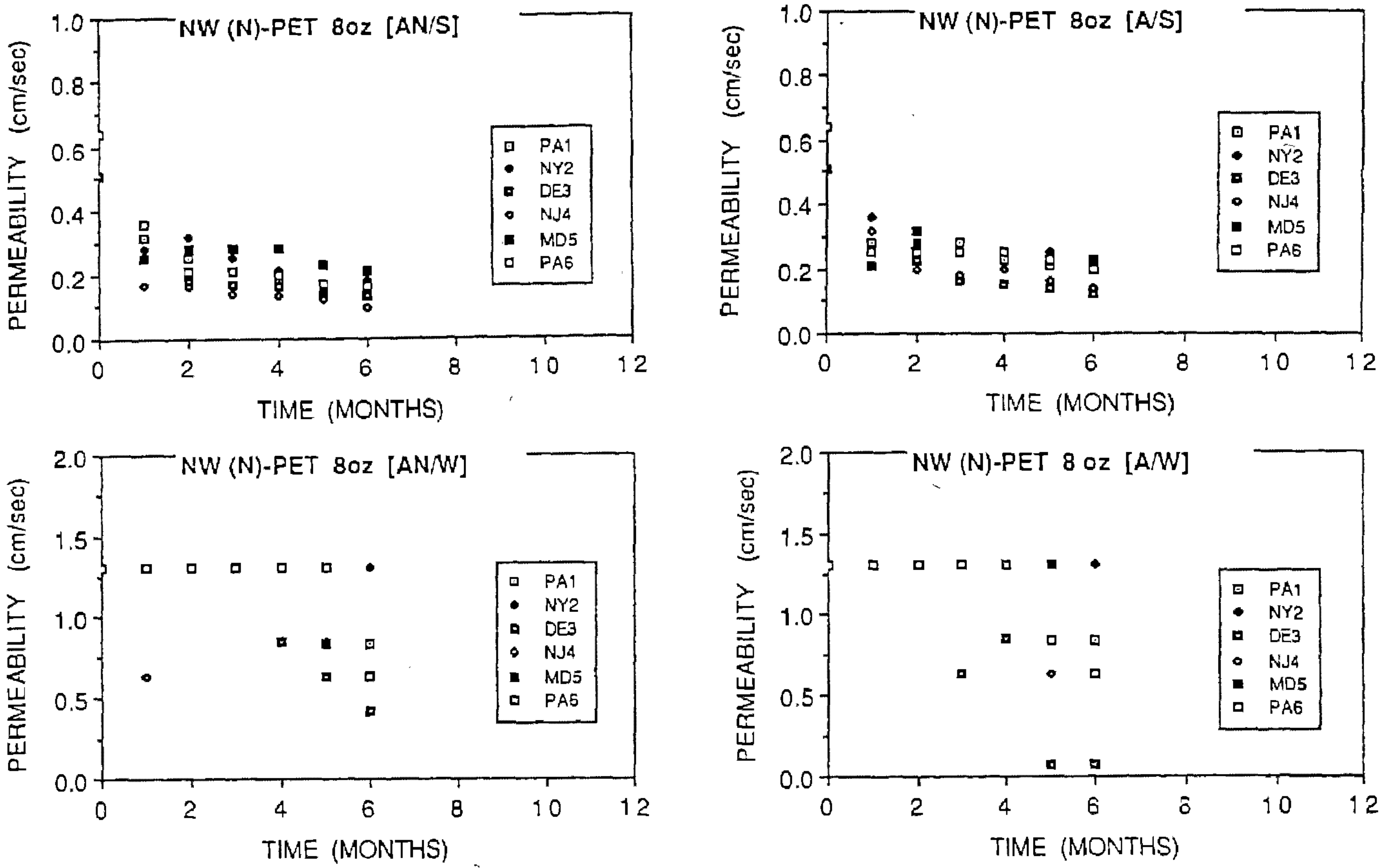


FIG. 10 -- Leachate Permeability Response from all Six landfills under four conditions for lightweight nonwoven needle punched geotextiles.

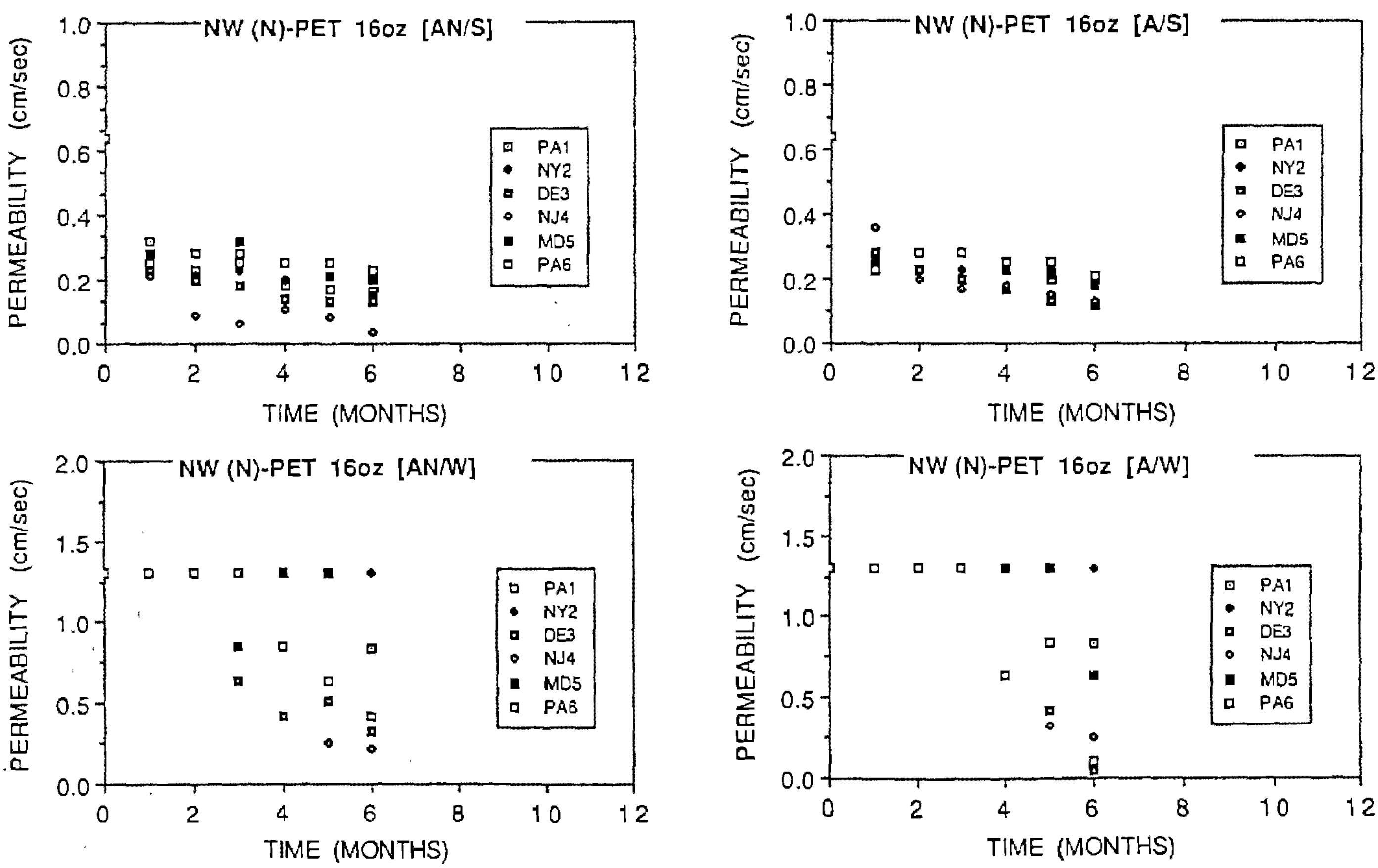
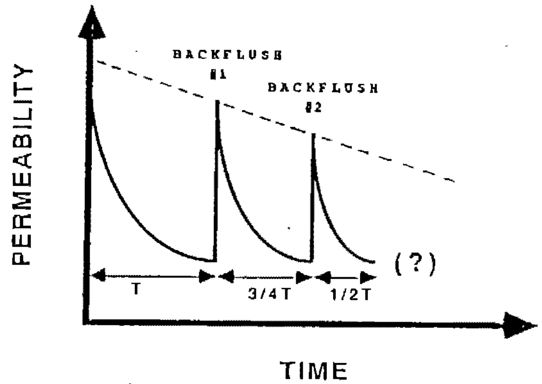
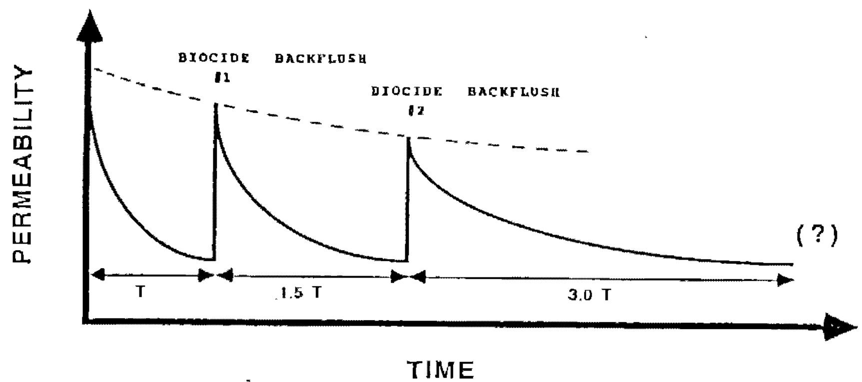


FIG. 11 -- Leachate permeability response from all Six landfills under



a) Hypothetical Leachate Backflush for Flow Remediation



b) Hypothetical Leachate Backflush with Biocide for Flow Remediation

FIG. 12 -- Anticipated flow patterns after repeated backflushing trials with leachate (upper curve) and with biocide treated leachate (lower curve).

TECHNICAL REPORT DATA

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

This paper presents the results of a biological growth study in geotextile filters used in landfill leachate collection systems. After reviewing the first year's activity, a completely new experimental approach has been taken. Using 100 mm diameter columns for the experimental incubation and flow systems, the effects of six landfill leachates are evaluated. Aerobic and anaerobic states, four different geotextiles, and soil/no soil conditions above the geotextiles are involved in the testing program. This results in 96 individual test columns. Flow data is measured regularly, and over the first six months of evaluation the following trends have been observed.

- no clogging (0% - 25% flow reduction)
  6 of 96 columns = 7%
- minor clogging (25% - 50% flow reduction)
  4 of 96 columns = 4%
- moderate clogging (50% - 75% flow reduction)
  37 of 96 columns = 38%
- major clogging (75% - 95% flow reduction)
  35 of 96 columns = 36%
- severe clogging (95% - 100% flow reduction)
  14 of 96 columns = 15%

For two of the landfill leachates, backflushing has been attempted so as to reinstitute flow. This procedure works well for the geotextile alone while not as well for the geotextile/soil columns. The exception is the nonwoven heat set geotextile. All tests are still ongoing and will be dismantled and further investigated at the end of 12 months exposure time. The experimental setup and procedure has been written up as a tentative ASTM test method and is currently in task group review.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
leaching	biological clogging, aerobic, anaerobic, soil clogging, geotextile clogging, leaching, bacteria count, viable count	

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