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A study on geotextile-leachate interaction by large laboratory tests

J.P. COLMANETTI, University of Brasilia, Brazil
E.M. PALMEIRA, University of Brasilia, Brazil

ABSTRACT: The prediction of geotextile filters performance in waste containment works is a complex problem. This paper presents a laboratory study on the interaction between leachate and granular and geotextile filters by means of tests in large cells. Different types of filter systems were tested. Microscopy analysis, evaluation of microorganisms growth and permitivitty tests on geotextile specimens after the tests were performed. The results indicate the potential for physical and biological clogging of the filter in this type of application. Significant reductions of filter permeability coefficient were observed, although for the duration of the experiments the filters tested performed satisfactorily.

1 INTRODUCTION

Geotextiles have been often used as filters in environmental protection works in combination with granular materials or geonets. In this type of application the flow of leachate through the filter layer can occur under uncontrolled and hence unsteady conditions. These circumstances, in addition to the characteristics of the fluid, can cause physical and biological clogging of the filter.

The study of filters in waste containment applications is a difficult task because of the complex physical, chemical and biological mechanisms involved. The simulation of filter behaviour in the laboratory under such conditions is also difficult due to the hazardous nature of the fluid and the variability of its properties in time. Test results of geotextile permeability to leachate can be found in important contributions in the literature (Cancelli and Cazzuffi, 1987, Cazzuffi and Cossu, 1993, Koerner and Koerner, 1990, and Fourier et al. 1994, for instance). Most of these tests are similar to those performed in conventional geotextile permittivity tests. Significant reductions of geotextile permeability under these test conditions are reported, mainly due to the sedimentation of material in suspension in the leachate, which can cause geotextile blinding. Exhumations of geotextile specimens from real works have also been carried out for the study of the performance of these materials under leachate flow. Corcoran and Bathia (1996) observed reductions of geotextile permeability by a factor of 10 times in tests on geotextile specimens exhumed from a landfill.

In waste disposal areas the leachate that reaches the filter may not be as concentrated as in some of the researches reported above. When no impervious cover layer is present at the top of the waste mass, the infiltration of water from rain dilutes the leachate. However, the transportation of solid particles toward the filter layer may still cause its physical clogging. Besides, the unsteady nature of the flow regime plus the fluid characteristics also increases the potential for chemical and biological clogging of the filter. In the long term, the combination all these mechanisms can severely reduce or totally clog the filter, increasing the potential for soil and groundwater contamination through leaks in the lining system.

This paper presents the results of part of a research programme being carried out at the University of Brasilia, Brazil, aiming to simulate filter performance under conditions closer to the actual in service conditions of a filter in waste disposal area. To accomplish that large tanks were used to study the interaction between domestic waste and filter layers, as described in the following itens.

2 EXPERIMENTALS

2.1 *Equipment and Test Methodology*

Four cells made of rigid steel tanks were employed to perform the tests reported in this paper. The cells were 580 mm in diameter and 815 mm high. Figure 1 presents the test arrangement for the four drainage systems tested. The drainage layers were installed at the bottom of each cell, below the domestic waste mass. The waste mass was mixed prior to testing and uniformly distributed among the tanks so as to have the same waste conditions and characteristics in all cells. A sand layer covered the top of the waste layer in all experiments. The internal walls of the cells were lubricated with oil and double plastic layers to minimise friction between waste and cell internal walls.

The drainage systems tested consisted of a gravel layer (cell 1 in Figure 1), two gravel layers with different geotextile filters (cells 2 and 3) and sand and gravel layers (cell 4).

The amount of leachate produced during the first two months of observations was due only to the initial waste moisture content and waste degradation. After that, water was added weekly to the system using a rotating pluviation device installed at the top of each cell. Thus, after the 68th day of testing, 5 liters/week of water were pluviated uniformly on the sand layer on top of the waste mass in single stages. This water pluviation aimed to simulate infiltration of water from rain and to favour bacterial activity in the waste mass.

Waste temperature and chemical composition of the effluent were measured during the tests as well as microorganisms growth in the filters. The variation of effluent volume with time was also measured. After the test duration specimens of the drainage systems were submitted to additional testing such as permitivitty for geotextiles as well as analysed through microscopy.

2.2 *Materials used in the tests*

The composition of the waste employed in the experiments is summarised in Table 1. It can be observed that 82.3% of the waste weight comes from organic matter. The waste mass was compacted in each cell yielding a final density of 827 kg/m^3. The average initial moisture content of the waste was equal to 58%. The final waste mass placed in each cell was approximately 193 kg.

The main characteristics of the granular materials (sand and gravel) used for drainage and filtration are presented in Table 2. The main geotextile characteristics are summarised in Table 3. Two non woven, needle punched, geotextiles made of polyester were employed as filters for the granular materials. Geotextile GA (Table 3) has a mass per unit area of 600 g/m^2 and is thicker than geotextile GB, which has a mass per unit area equal to 300 g/m^2. The filtration opening size (hydrodynamic sieving) of geotextile GB is approximately half that value for geotextile GA.

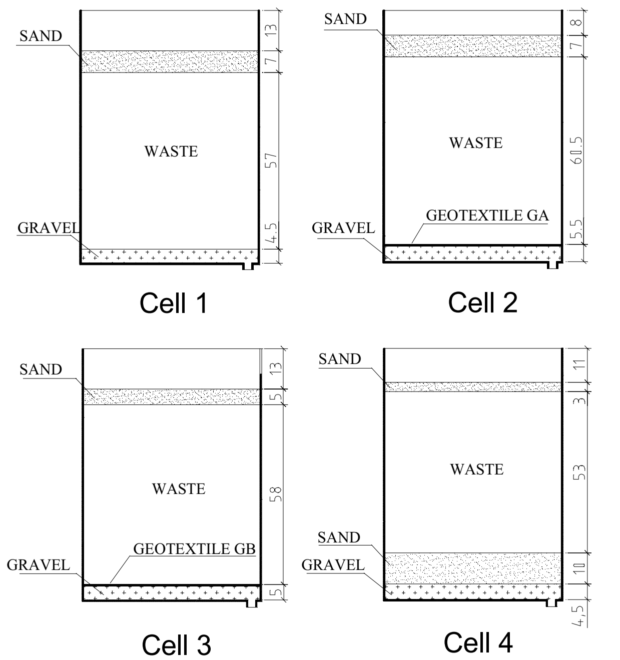

Figure 1. Waste cells.

Table 1. Waste composition.

	Percentage in weight (%)
Organic matter	82.3
Paper	9.8
Soft plastics	3.9
Others	4.0

Table 2. Characteristics of the granular filter materials.

	Sand	Gravel
D_{10} (mm)	0.25	9
D_{50} (mm)	0.76	13
D_{85} (mm)	2.70	18
CU	3.04	1.44
G	2.73	2.75

Note: D_n = diameter corresponding to n% passing, CU = coefficient of uniformity and G = soil particle specific gravity.

Table 3. Characteristics of the geotextiles used in the tests.

Property	GA	GB
Mass per unit area (g/m^2)	600	300
Thickness at 2 kPa normal stress (mm)	4.5	2.6
Porosity (%)	90	92
Normal permeability (cm/s)	0.24	0.4
Permittivity (s^{-1})	0.9	1.5
In-plane permeability (cm/s)	0.6	0.6
Transmissivity (cm^2/s)	0.27	0.13
Filtration opening size – FOS (mm)	0.06	0.11
Aparent opening size – AOS (mm)	< 0.11	0.12-0.17

Notes: FOS and AOS values obtained according to CFGG (1986) and ASTM (1995), respectively.

Additional information on equipment, materials and methodology can be found in Colmanetti (2000) and in Colmanetti and Palmeira (2001).

3 RESULTS

Figure 2 shows the variation of the volume of effluent from the cells normalised by the waste mass. It is clear that the production of leachate was smaller in cells 2 (geotextile GA) and 4 (sand + gravel). This may have been caused by the greater difficulty of the leachate to pass through the thicker geotextile and the sand layer in each case. Chemical analyses of the effluents from the cells showed that the Chemical Oxygen Demand (COD) at the beginning of the tests was of the order of 120,000 mg/l, decreasing to values between 60,000 and 90,000 at the end of the tests, depending on the cell considered, after almost 6 months of observations. The lowest COD at the end of the test was observed for cell 4 (sand and gravel) and was caused by the greater retention capacity of the sand filter. At the end of the research period, the values of COD for the effluents of cells 1, 2 and 3 were approximately the same (≅ 90,000 mg/l). Similar trends were observed in tests in experimental waste cells of different sizes in the field (Junqueira, 2000, Junqueira and Palmeira 2000).

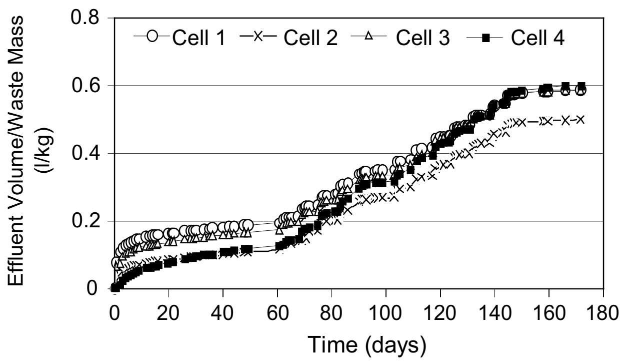

Figure 2. Effluent volume versus time in the waste cells.

The values of pH of the effluent from the cells varied between 3.7 and 5.5 during the duration of the tests, depending on the cell considered. The highest values of pH were observed for cell 4, while cells 1 to 3 presented similar variations of effluent pH with time (Colmanetti and Palmeira, 2001).

Table 4 shows the percentage of total solids, solids in suspension and total dissolved solids in the effluent of each cell. Taking the effluent of cell 1 as a reference, because there was no filter in this cell, one can obtain the percentage of total solids in the effluent retained by each filter system in cells 2 to 4, as shown in Table 5. It can be noted that the systems comprising the sand layer and the thicker geotextile (GA) were the ones retaining the largest percentages of total solids. These results suggest that the systems in cells 2 and 4 are likely to clog sooner than that in cell 3 (geotextile GB).

Table 4. Solids contents in the leachate.

Cell No.	Total Solids (mg/l)	Solids in Suspension (mg/l)	Total Dissolved Solids (mg/l)
1	71121	---	---
2	25926	576	25350
3	44968	2276	42692
4	24658	692	23966

Figure 3 shows the distribution (in volumetric terms) of the size of particles in the effluents immediately after their release in each cell in the 160th day of testing. The results depicted in that figure were obtained using a laser grain size analyser. The results show that the particle dimensions in the effluent from cell 4 (sand and gravel) were the finest, followed by the particles in the effluent from cell 2 (geotextile GA). Very little differences were observed between the results obtained for cells 1 (no filter) and cell 3 (geotextile GB). These results confirm the greater retention capacity of the sand and of geotextile GB and are consistent with the results in Table 4. It should be noted that the shape of the curves and particle diameters obtained from the results in Figure 3 are time dependent because they include diameters of degradable particles composed by organic matter. The maximum particle diameters passing through geotextiles GA and GB were very similar and greater than the filtration opening sizes of these geotextiles. This difference may have been caused by the agglutination or shape of particles of organic nature, flocculation of particles or microorganisms growth after leachate sampling and limitations of this type of test for leachate. Further investigation is required on this matter. Nevertheless, the relative comparison between results gives a qualitative assessment of the filtering potential of each filter tested at the time the measurements were made.

Table 5. Particles retained in the filters.

Cell No.	Total solids (mg/liter)	Percentage in comparison with cell 1 (%)
2	45195	63.6
3	26153	36.8
4	46463	65.3

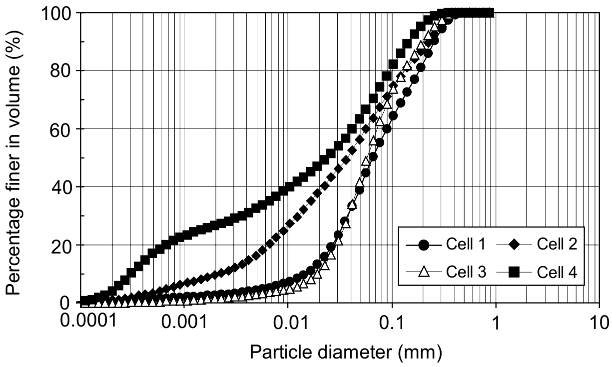

Figure 3. Particle size distribution of the effluent from the cells.

At the end of the tests five specimens were taken from each geotextile layer and tested for normal permeability, following the methodology proposed by ASTM (1995). The aim was to assess the residual permeability coefficient retained by the geotextile after 6 months of testing. The results of normal permeability obtained are presented in Table 6. The hydraulic gradient imposed to the geotextile specimen was increased during the test to observe if the geotextile permeability would increase as a result of the washing out of the particles entrapped in the geotextile. In most of the cases the increase in geotextile permeability caused by gradient increase was small. Figure 4 shows the comparisons between the permeability of the exhumed geotextile specimens and the range of variation observed these geotextiles under virgin conditions. Reductions of geotextile normal permeability of the order of 55 to 90% can be observed. The average permeability reduction for geotextiles GA and GB was approximately 80%.

The amount of solids (non-degradable) entrapped in the geotextile fibers gives an assessment of the potential of physical clogging of the geotextile. Table 7 presents values of geotextile impregnation ratio (λ) for exhumed geotextile specimens. The impregnation ratio is defined as the mass of entrapped particles per unit area of the geotextile divided by the mass of the geotextile fibers per unit area. The values of λ varied between 0.85 and 3.39, depending on the geotextile specimen considered. Theoretical analyses on the effect of the impregnation ratio on the geotextile permeability were presented in Palmeira and Gardoni (2000). For λ varying between 0.8 and 3.4 the prediction of permeability coefficient reduction by the theoretical analysis yielded values between 50 to 89%. From Figure 4, depending on the geotextile specimen considered, the reductions of permeability coefficient varied from 44 to 90%, close to the range obtained by the theoretical predictions based only on the influence of the presence of non-degradable solids in the geotextile voids. This may suggest that for the tests duration the influence of entrapped organic matter or biofilms on the reductions of geotextile permeability may have been less relevant.

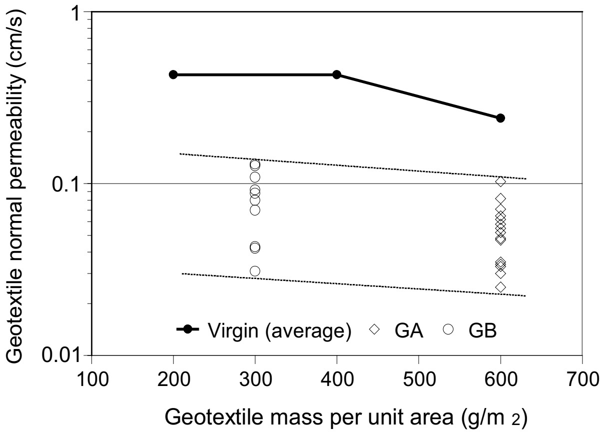

Figure 4. Comparison between permeability coefficients of exhumed and virgin geotextile specimens

Table 6. Geotextile residual permeability.

Geo-textile	i	Permeability coefficient (cm/s)				
		1	2	3	4	5
GA	5	0.058	0.025	0.030	0.055	0.062
	14	0.048	0.033	0.035	0.065	0.082
	31	0.047	0.052	0.034	0.071	0.103
GB	8	0.127	0.088	0.042	0.043	0.070
	21	0.130	0.109	0.031	0.080	0.092

Notes: (1) i = hydraulic gradient, (2) specimen number.

Table 7. Impregnation ratio of exhumed geotextile specimens.

Geotextile	Specimen No.	λ
GA	1	1.41
	2	1.68
	3	0.85
GB	1	1.76
	2	3.39
	3	1.95

Table 8 shows the results of the analyses of microorganism growth in the geotextiles and in the sand after testing in terms of total numbers of colony forming units (CFU) and number of colony forming units per unit fiber (or grain) surface area and per unit filter void volume. The results of CFU per fiber surface area obtained for geotextiles GA and GB were approximately 74 and 69 times that value obtained for the sand filter, respectively. These differences may be partially explained by the fact that most of the microorganisms in the geotextile voids must have been considered in the counting for these filters, whereas for the sand the collection of specimens (disturbed) for testing may have reduced the influence of the amount of microorganisms present in the sand voids in the final counting. During exhumation of the filter materials the geotextiles were clearly wetter than the sand layer, as it can be observed in the microscopic view of one of the geotextiles at the end of the test, shown in Figure 5. It should be pointed out that the calculation of CFU per unit fiber (or grain) surface area, or per unit void volume, assumes that all the microorganisms were attached to the geotextile fibers, or in the voids, which in certainly not the case. The results obtained for geotextiles GA and GB presented in Figure 4 and Table 7 agree with the comments by Rollin (1996) and Giroud (1996) that more open geotextiles are likely to be less affected by biological clogging than heavier ones.

Table 8. Microorganisms growth in the filters

Filter	Number of CFU(1)	CFU/void volume(2)	CFU/area(3)
Sand	4.25×10^4	1.97×10^4	1.56×10^2
Geotextile GA	8.55×10^6	2.41×10^6	1.15×10^4
Geotextile GB	3.55×10^6	1.86×10^6	1.09×10^4

Notes: (1) CFU = colony forming units, (2) Number of CFU per unit filter void volume (units/cm^3), (3) Number of CFU per unit fiber (or grain) surface area (units/cm^2).

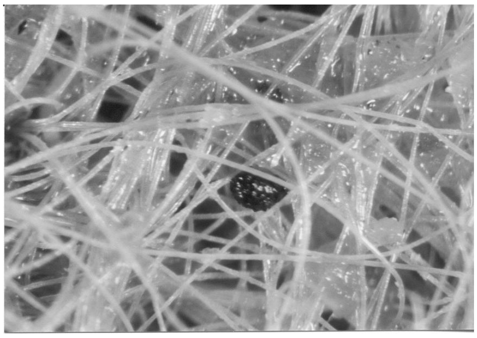

Figure 5. Microscopic view of one of the geotextiles after the end of the test (55 x enlargement, 1 fiber diameter = 0.026 mm).

CONCLUSIONS

This paper presented experimental studies on the performance of granular and synthetic filters in domestic waste disposal works by means of large cells. Gravel, sand and two geotextile filters were tested. The results obtained are summarised below.

The sand layer was the filter that retained the largest amount of solids in its voids, followed by the thicker geotextile and approximately twice as much solids as the quantity retained in the voids of the thinner and lighter geotextile. The geotextiles tested presented average reductions of normal permeability of of the order of 80%. The results suggest that for the duration of the tests physical clogging was more relevant than biological clogging, although the necessary conditions for the development of the latter were also identified.

The number of microorganisms colony forming units in the geotextile filters was greater than in the sand filter. For the duration of the tests, despite the permeability losses, the filters tested performed satisfactorily. In spite of the natural limitations in modelling actual conditions in landfills, the results obtained in this work suggest that the evaluation of geotextile filter performance using concentrated leachate, with high levels of solids in suspension, may be too severe compared to the situation these materials are likely to be subjected in the field. Further research is required for the investigation of the long term performance of filters subjected to leachate flow and the effects of physical and biological clogging.

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REFERENCES

ASTM 1995. *ASTM standards on geosynthetics*. American Society for Testing and Materials, ASTM Committee D-35, Philadelphia, PA, USA, 178 p.

Cancelli, A. and Cazzuffi, D. 1987. Permittivity of geotextiles in presence of water and pollutant fluids. In *Geosynthetics'87*, New Orleans, USA, Vol. 2: 471-481.

Cazzuffi, D. and Cossu, R. 1993. Experimental evaluation of filter performance for geotextiles in landfills. In *Geotextiles in Filtration and Drainage*, S. Corbet and J. King Eds., Thomas Telford, London: 78-94.

CFGG 1986. *Normes Françaises D'Essais*. Comité Français des Géotextles et Géomembranes.

Colmanetti, J.P. 2000. Geotextile filter behaviour in drainage systems for municipal solid waste. *MSc. Thesis*, University of Brasilia, Brasilia, Brazil, 125 p. (in Portuguese).

Colmanetti, J.P. and Palmeira, E.M. 2001. Large filtration tests on drainage systems subjected to leachate flow. In XV International Conference on Soil Mechanics and Geotechnical Engineering, Istanbul, Turkey, ISSMGE.

Corcoran, B.W. and Bathia, S.K. 1996. Evaluation of geotextile filter in a collection system at Fresh Kills landfill. In *Recent Developments in Geotextile Filters and Prefabricated Drainage Geocomposites*, S.S. Bhatia and L.D. Suits Eds.. American Society of Testing and Materials, ASTM STP 1281, 182-195.

Fourier, A.B., Kuchema, S.M. and Blight, G.E. 1994. Effect of biological clogging on the filtration capacity of geotextiles. In *5th International Conference on Geosynthetics*, Singapore, Vol. 2: 721-724.

Giroud, J.P. 1996. Granular filters and geotextile filters. In *GeoFilters'96*, J. Lafleur and A.L. Rollin Editors, Montreal, Canada: 565-680.

Koerner, G.R. and Koerner, R.M. 1990. Biological activity and potential remediation involving geotextile landfill leachate filters. ASTM STP 1081, R.M. Koerner Ed., Philadelphia, PA, USA.

Junqueira, F.F. 2000. *The performance of solid waste and drainage systems in different testing scales with reference to the Joquei Clube dump-DF*. PhD Thesis, Department of Civil and Environmental Engineering, University of Brasilia, Brazil, 288 p. (in Portuguese).

Junqueira, F.F. and Palmeira, E.M. 2000. A study on the behaviour of domestic waste under controlled conditions. In *5th International Symposium on Environmental Geotechnology and Global Sustainable Development*, Belo Horizonte, MG, Brazil, 8 p.

Palmeira, E.M. and Gardoni, M.G. 2000. The influence of partial clogging and pressure on the behaviour of geotextiles in drainage systems. In *Geosynthetics International*, 7(4-6): 403-431.

Rollin, A.L. 1996. Bacterial clogging of geotextiles. In *GeoFilters'96*, J. Lafleur and A.L. Rollin Editors, Montreal, Canada: 125-134.