# Effect of Biological Clogging on the Filtration Capacity of Geotextiles

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ABSTRACT: There is increasing awareness of the potential for biological clogging of the leachate collection systems beneath Municipal Solid Waste landfills. This study investigated the effect of exposure to leachate of three different geotextiles. Falling head tests were carried out in a modified permeameter using a four day interval between tests. Aerobic conditions were allowed beneath the underside of the geotextile tested, and the leachate was collected from a landfill that was in the methanogenic phase of development. Comparative tests were carried out using tap water. In the tests using landfill leachate, biological clogging resulted in up to 80% loss in hydraulic conductivity in only one month, whereas with tap water losses stabilised at about 20%. In the light of the findings of this study, together with previously published results, it is suggested that a potential solution is the treatment of geotextiles with an antimicrobial agent at the time of manufacture.

## 1 INTRODUCTION

The use of geotextiles as an integral component of the drainage system beneath Municipal Solid Waste (MSW) landfills is becoming increasingly widespread. In many parts of the world, the climate is such that infiltration of rainfall into, and through a landfill results in the generation of leachate at the base of the landfill. This leachate inevitably contains high concentrations of various contaminants, and measures must be taken to prevent ingress of the leachate into the local groundwater system.

A typical leachate and drainage collection system is shown in Figure 1. A geotextile is usually placed below the waste, and often covered with a protective soil layer. The function of the geotextile is to allow the passage of leachate into the drainage collection system, and thence to a sump for subsequent treatment or recycling. In addition, the geotextile must act as a barrier to the movement of waste and other particulate matter into the drainage system.

A concern that has arisen with the use of geotextiles in this type of application is the potential for biologically induced clogging of the geotextile. A landfill is essentially a very large bioreactor, and high concentrations of bacteria occur within the body of a landfill, eg Rios and Gealt (1989) detected between $10^8$ and $10^9$ cells per ml of leachate, with 35-60% viability of the cells. According to Hamilton et al (1989), the bacteria attach to a surface, such as a geotextile fibre or inside wall of a drainage pipe, and thereafter excrete a substance that forms a layer of bioslime around the bacteria. This substance adsorbs and concentrates inorganic and organic matter from the leachate, in order to use this matter as nutrients for the embedded organisms. A property of geotextiles that makes them potentially susceptible to bio-clogging is their relatively small pore sizes, which facilitate adhesion of the bacteria, as well as rapid clogging because of the small open area available for drainage.

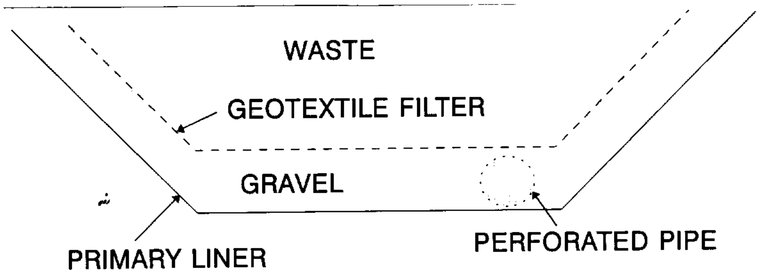

Figure 1: Typical leachate collection system

The consequences of clogging of the geotextile layer beneath a landfill are ponding of the leachate above the geotextile, ultimately resulting in the emission of contaminated water to the environment and/or stability problems with the side slopes of the landfill due to the build-up of pore water pressures. Increasingly, evidence is being published where problems of the above type have been encountered. According to Brune et al (1991), in the late 1980's many instances of loss of drainage efficiency were reported, and at the time there was little unanimity on the causes of the problems. More recently, McBean (1993) reported on a problem in Peterborough, Canada, where leachate mounding was found to be causing leachate seeps along the outside face of the landfill. The problem was traced to clogging of toe drains located around the outside of the landfill.

Although potential bio-clogging is therefore a very real problem, it is unclear under what conditions it is most problematic. Aerobic conditions are considered to be more conducive to bio-clogging than anaerobic conditions, and leachate generated by a landfill in the acetogenic phase is more problematical than leachate from a methanogenic phase landfill. However, as discussed later in the paper, experimental results have not always confirmed these assumed generalisations, and there is a great need to obtain data from a range of geotextile/leachate combinations.

This paper describes the results of a series of experiments on three different geotextiles exposed to leachate from an operational MSW landfill. The experimental procedure was varied slightly from that reported in the literature, in order to account for the possible cyclic nature of leachate generation, (Koerner and Koerner, 1989).

## 2 METHODOLOGY

### 2.1 Experimental Apparatus

It was decided to use an apparatus similar to that developed by Koerner and Koerner (1989). The advantages were that the equipment is inexpensive and relatively easy to manufacture, coupled with the fact that it has been agreed as a potential standard test for the susceptibility of geotextiles to bio-clogging. The apparatus is essentially a permeameter, wherein the geotextile was supported on a geogrid, and sealed onto the inside wall of the permeameter. It was covered with 20cm of soil, which acted as a primary filter for the suspended solids present in the leachate. It was also meant to simulate the soil working blanket that is often placed above the primary leachate collection system, as discussed earlier. Falling head tests were carried out every four days with landfill leachate. Between each test, drainage of the geotextile and adjacent soil was allowed to occur. The justification for this approach was that observations on the few landfills in South Africa that generate leachate indicate that it is very temporal in nature, and only occurs for a few days at a time. Subjecting the soil/geotextile system to a continual flow of leachate was therefore regarded as substantially different from in-situ conditions.

In experiments of the type discussed here, the inevitable query is raised as to whether aerobic or anaerobic conditions should be used. A design such as that indicated in Figure 1 is likely to result in aerobic conditions at the underside of the geotextile, which is what was simulated in our tests. Furthermore, opaque material, as well as a tapered base section were used in order to exclude light, as would be appropriate to the in-situ conditions.

Despite the assumption that anaerobic conditions reduce the potential for bioclogging, (eg McBean et al, 1993) recommend that in order to counter the problem at the Peterborough site, a wet sump should be installed), experimental evidence does not bear this out. Koerner and Koerner (1989) carried out tests using both aerobic and anaerobic conditions, and found no significant difference between the results. In general, they found a 5-10 fold decrease in flowrate over a period of 200-300 days. Cazuffi et al (1991) carried out tests in which strictly anaerobic conditions were maintained, and various geotextiles were tested in isolation (ie no soil cover). They found extremely dramatic decreases in permeability, with a five order of magnitude decrease taking place in under forty minutes. However, as discussed later in the paper, this may have been largely due to accumulation of suspended solids within the geotextiles, rather that only biological clogging.

### 2.2 Materials Used

As discussed by Koerner and Koerner (1989), the particle size distribution of sediment and micro-organisms in landfill leachate typically falls within the silt-sized range. Therefore in order to provide filtration of this material, the soil chosen for the geotextile cover layer was a well-graded fine sand, with a saturated hydraulic conductivity of $4x10^{-4}$ cm/sec.

Three geotextiles which were representative of those used in South Africa were tested. Details of these geotextiles are summarised in Table 1.

Table 1. Details of geotextiles tested.

| Geotextile type | Woven (W1) | Woven (W2) | Nonwoven (NW) |
|---|---|---|---|
| Composition | PP | PP | PE |
| Thickness (mm) | 0.32 | 1.14 | 1.5 |
| Mass per unit area (g/m$^2$) | 128 | 282 | 150 |

(where PP ≡ polypropylene and PE ≡ polyester)

## 3 DETAILS OF LEACHATE USED IN THE STUDY

The MSW landfill from which the leachate was obtained is located approximately 25km north of Johannesburg in South Africa. It accepts about 0.15 million tonnes of waste per year, the composition of which is given in Table 2.

Average values for the leachate that was obtained from this landfill are given in Table 3.

Table 2. Proportions of various wastes in landfill.

| Description | Percentage of total volume (%) | Percentage of total mass (%) |
|---|---|---|
| Mixed refuse | 4.2 | 3.0 |
| Wood and garden refuse | 29.2 | 20.8 |
| Household waste, paper | 26.6 | 19 |
| Gravel, subsoil, bricks | 32.4 | 46.3 |
| Builders rubble | 7.6 | 10.9 |

Table 3. Average values for leachate used in the study.

| Parameter | |
|---|---|
| pH | 7.5 |
| Conductivity (mS/m) | 357 |
| Chemical Oxygen Demand | 1300 |
| Ammonia as N | 72 |
| Nitrate as N | 1.1 |
| Alkalinity as $CaCO_3$ | 915 |
| Chloride as Cl | 518 |
| Calcium as Ca | 143 |
| Iron as Fe | 755 |
| Suspended solids | 2153 |

(all results in mg/l except pH and conductivity)

All the results in the above table, with the exception of iron, indicate that the landfill in question is in the methanogenic phase of development, according to the results published by Pohland et al, (1983). The iron concentrations are about 2-3 times higher than Pohland et al's upper values. This may be attributed to the large proportion of rubble, bricks, and subsoil in the landfill (see Table 2). As a result of the widespread occurrence of ferricrete horizons around the Johannesburg area, high iron concentrations could exist in these materials. According to the criteria of Brune et al (1991) the leachate could be considered to be lightly loaded in terms of contamination potential.

## 4 EXPERIMENTAL RESULTS

The experimental results are summarised in Figure 2. Each line is the average for three replicate tests. Figure 2a presents the results in terms of the measured flowrate, whilst Figure 2b is in terms of the percentage of the original flowrate that is retained.

It is evident that the effect of using leachate as permeant liquid is to markedly reduce the drainage efficiency of the soil/geotextile system, for all three geotextiles tested. The drop in flowrate that occurs with only tap water is attributable to hydrodynamic compaction, and the movement and accumulation of fine soil particles and suspended sediment within the soil cover. Of importance is the observation that in these circumstances the permeability loss stabilises rapidly (ie the 20% decrease remains constant after about 20 days), whereas with leachate the decrease in flowrate appears to be ongoing, and when the tests were terminated after 32 days, had not stabilised.

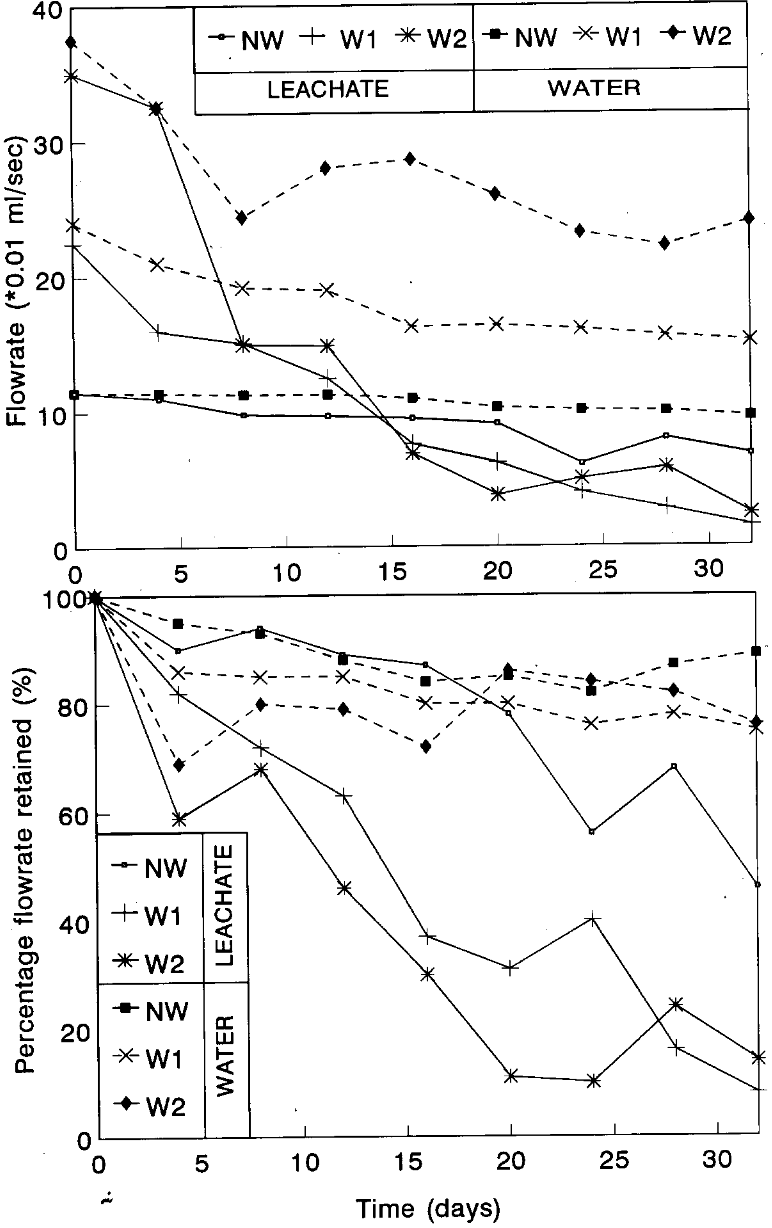

Figure 2: Experimental results; a) Flowrate variation with time, and (b) Percentage of retained flowrate.

Although the nonwoven geotextile has an initially lower permittivity, the loss of drainage efficiency under conditions of leachate flow is significantly less than for the two woven geotextiles.

At the end of the tests, the geotextiles were inspected under an electron microscope. Geotextiles that were exposed to leachate clearly showed marked accumulation of bacteria on the downstream face of the geotextile. Clearly visible were bacteria that were identified as

Alternaria, which is a bacterium commonly found in compost heaps. It is suggested that the testing procedure used in this study, of allowing aeration of the geotextile for four days between each application of leachate, resulted in the very rapid bioclogging of the geotextiles. Previously published data (Cazuffi et al, 1991), found that clogging tended to take longer than was found in the present study, which could be due to their tests utilising continually running leachate. It is also worth noting that in our tests there was no evidence of chemical precipitation on either the geotextile fibres, or the bacteria. The sequence of build-up of precipitate that was discussed earlier (chemical precipitation occurring on established bacterial colonies and associated bioslime), had therefore not had time to initiate at the time the tests were terminated. Despite this, the loss in drainage efficiency was dramatic, and clearly unsatisfactory.

An indication of the biomass accumulation on the geotextiles exposed to leachate is given in Figure 3, which shows the gain in mass of the geotextiles, as compared with their initial mass. Exposure to leachate results in an approximately 4 fold increase, as compared with exposure to tap water. It is also interesting to compare these results with those of Cazuffi et al (1991), who tested geotextiles in isolation, and measured gains in mass of over 200%. The conclusion to be drawn from this is that the soil cover had the desired effect of filtering out fine soil particles and suspended sediment, prior to the leachate passing through the geotextile. The electron microscope results confirmed this conclusion, as no soil particles were observable within the geotextile structure.

## 5 DISCUSSION AND EVALUATION

The results discussed in this paper confirm findings published in the literature, in the sense that geotextiles used in leachate collection systems below MSW landfills are susceptible to severe biological clogging. An important result that was found in the present study, was that allowing quiescent periods, during which the soil - geotextile system was allowed to drain under gravity, resulted in much more rapid clogging than has previously been reported in the literature.

It is difficult to draw any generalised conclusions from the work presented in this paper, together with previously published data, as to which factors most favour biological clogging. There is contradictory data as to the relevance of aerobic versus anaerobic conditions within the drainage system, as well as the importance of the leachate composition. Our understanding of the microbiological factors is too limited at this stage to conclude anything other than that biological clogging is a very real concern, and ameliorative measures to address this problem are vital. Furthermore, it is not only geotextiles that may be susceptible to biological clogging. As shown by Mitchell et al (1993), exposure of a sandy gravel to a MSW landfill leachate resulted in decreases of permeability of two orders of magnitude

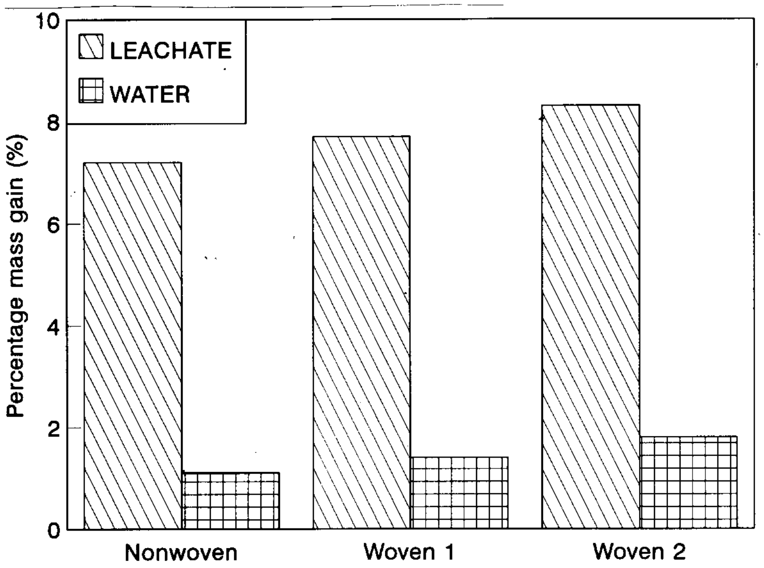

Figure 3: Increase in mass of geotextiles

A possible solution could be the addition of an antimicrobial agent to the geotextile during the manufacturing process, as suggested by Hamilton et al (1989). This inhibits the attachment of bacteria to surfaces, as well as reducing the adhesive strength of bioslime.

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