A STUDY ON THE BEHAVIOUR OF ALTERNATIVE DRAINAGE SYSTEMS IN LANDFILLS

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SUMMARY: Drainage and liquid collection systems are components of fundamental importance in landfills and waste disposal areas. Sand, gravels and geosynthetics are materials commonly used as filters and draining media in landfill drainage systems. However, the waste itself contains elements that could be employed as drainage material. This paper presents an investigation on the use of recycled rubble and tires (whole and shreds) as drainage materials of domestic waste disposal areas in combination with geotextile filters. Two large experimental cells and two metallic containers were employed in the research. The results showed the potentials of the use of alternative drainage materials in combination with geotextile filters in drainage systems of landfills.

1. INTRODUCTION

A satisfactory behaviour of a drainage system in a landfill is of utmost importance for its overall performance and to minimise environmental damages in case of leakages to the natural ground. Clogging of the drainage system will cause the mounding of leachate on the lining system, increasing the flow rate of leachate through defects in that system. Thus, a well design and constructed drainage system should be able to collect the leachate and conduct it accordingly. Besides, it should also be able to perform its role throughout the entire life time of the landfill.

Drainage systems in landfills are subjected to very complex conditions. Leachate is a very heterogeneous fluid with high content of organic matter and solids in suspension and because of such characteristics prone to cause clogging of filters and liquid collection systems. Natural and synthetic drainage and filter materials have been used in landfills. However, in several occasions the use of traditional natural materials (sand and gravel) is difficult due to their scarcity in the region or restrictions to their exploitation because of environmental regulations. In contrast with this situation, some materials that might be recycled and used in such drainage systems are disposed in landfills on a daily basis. These are the cases of several types of plastic objects, PET bottles, tires and rubble from demolition works, for instance. Some of these materials may take decades or centuries to degrade in the landfill and will continue to be environmental hazards for a long time besides occupying a significant amount of space in the landfill that might be better

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used.

This paper presents a study on the use of alternative and non conventional materials in drainage systems of landfills. This subject is particularly relevant to the region where the research was conducted, as natural granular materials are scarce in the Brazilian Federal District or protected by environmental laws and hence very expensive. The drainage materials investigated were whole tires, shredded tires and gravel from processed rubble in combination with non woven geotextile filters. Large scale tests were performed on experimental waste cells and waste containers and their characteristics and results obtained are presented as follows.

2. EQUIPMENT AND METHODOLOGY USED IN THE TESTS

2.1 Experimental Waste Cells

As part of the research programme, two instrumented domestic waste cells were constructed for the investigation on the use of alternative drainage materials in landfills. Figures 1(a) and (b) present the geometrical characteristics of these cells. The dimensions of the cells were 15 m x 5m x 2.4 m with both cells having vertical longitudinal walls. The mass of domestic waste in each cell was approximately 50 ton and they were constructed inside the facilities of the Joquei Club Dump, in Brasilia, Federal District, Brazil.

Drainage trenches were located at the centre of the bases of the cells and were 0.3 m wide and 0.3 m deep (Figs. 1a and b). A perforated pipe (100 mm in diameter) was installed close to the bottom of the trench of each cell. The trenches directed the leachate produced to reservoirs adjacent to the cells, where leachate flow rate was measured with time and samples of the leachate were taken for chemical analyses.

The waste was compacted using the practice employed in the Joquei Club dump, which consisted of passages of a bulldozer on the waste mass. The average bulk unit weight of the waste was equal to 5.4 kN/m^3, which can be considered a result of moderate compaction, according to Fasset et al. (1994). A clayey soil layer, 0.5m thick, was used as final cover of the cells. Table 1 shows the main characteristics of the cover soil.

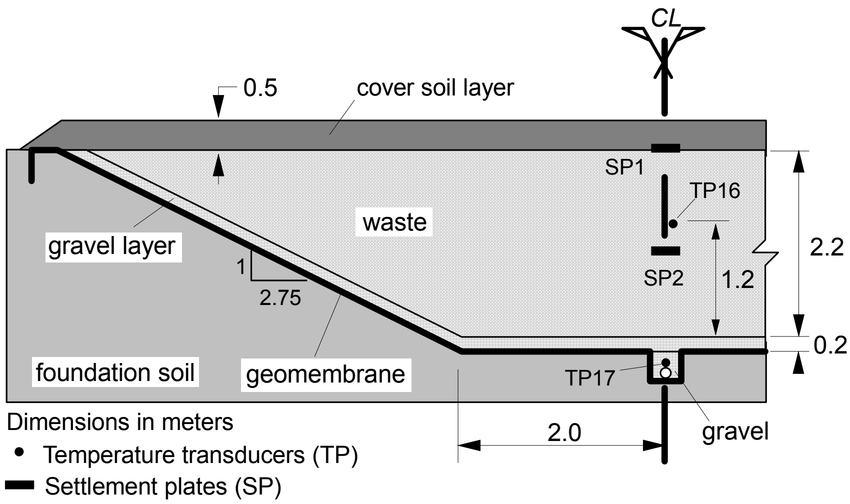
To avoid contamination of the foundation soil and to maximise leachate collection HDPE geomembranes were used as barriers and covered the entire bottom and side areas of the cells (Figures 1a and b). It should be noted that the foundation soil in the site consists of a residual clay with high void ratio and values of hydraulic conductivities as high as 10^{-4} cm/s have been recorded for this clay. Close to the dump site there are a national park and small farms, which enhances the concern regarding the need for an environmental protection scheme for that area (Junqueira and Palmeira, 2002).

The instrumentation of the waste cells consisted of settlement plates, for monitoring waste settlement with time, and temperature transducers in different locations, as shown in Figures 1(a) and (b). Temperatures were always measured between 8 am and 10 am. A rain gauge measured the precipitation on the site, which allowed relating precipitation to leachate production with time. Measurements of leachate discharge with time were taken in the leachate storage tanks adjacent to the cells. Samples of leachate were periodically taken and subjected to physical and chemical analyses. Physical and chemical tests on the leachate comprised chemical oxygen demand (COD), nitrate content, ammoniac nitrogen, chloride content, electric conductivity, solids in suspension and pH. Chemical tests followed the recommendation by the American Public Health Association (APHA, 1996).

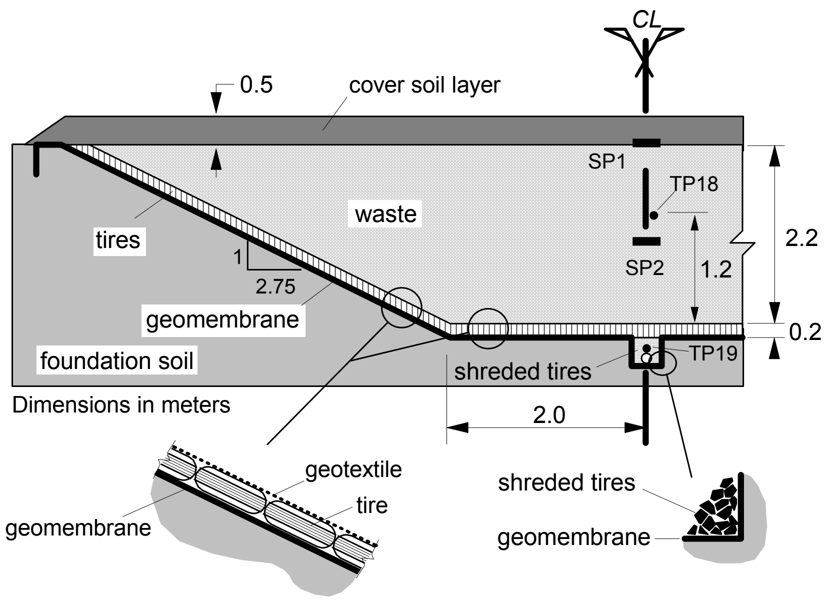
A natural gravel layer 0.2m thick was used for drainage in cell CGR and its main characteristics are listed in Table 1. Whole tires formed the drainage layer of cell CT. The draining material used in the trench of cell CGR was gravel, whereas shredded tires were used as draining material in the trench of cell CT. The relevant characteristics of the shredded tires are summarised in Table 2. No filter was used in cell CGR whereas in cell CT a light weight (150 g/m^2) non woven geotextile layer whose main characteristics are presented in Table 3 was used as filter.

The cells were filled with typical waste that is disposed daily in the dump and that came from specific locations in the city to guarantee some level of uniformity. The average waste composition was: organic matter (49% in weight), plastics (18%), paper (13%), cardboard (9%), metals (2%) and others (9%). It should be noted the large amount of organic matter, which is typical of Brazilian landfills.

Additional information on the characteristics of the materials used and test methodology can be found in Silva (2004) and Junqueira et al. (2006).



(a) Cell CGR



(b) Cell CT.

Figure 1. Characteristics of the experimental waste cells (Junqueira et al. 2006).

Table 1. Characteristics of the soils used in the experimental cells.

	Gravel	Cover soil[3]
D_{10} (mm)[1]	53	---
D_{50} (mm)	60	---
D_{85} (mm)	65	0.20
CU[2]	1.2	---
Dry unit weight (kN/m^3)	19.7	13.4
Permeability (cm/s)[4]	24[5]	0.003 to 0.009

Notes: (1) D_{10}, D_{50} and D_{85} are diameters of soil particles for which 10, 50 and 85% in weight are smaller than those diameters, respectively; (2) CU = soil coefficient of uniformity = D_{60} /D_{10}, where D_{10} and D_{60} are diameters for which 10 and 60% in weight of the soil particles are smaller than those diameters; (3) 79% in weight smaller than 0.074 mm in grain size analyses using dispersing agent; (4) From infiltration tests on the cover soil in the field (Junqueira 2000 and Silva 2004); (5) From large scale constant head permeability tests (Paranhos and Palmeira, 2003); (6) Soil characterisation tests performed according to Brazilian standards.

Table 2. Characteristics of the tire shreds.

D_{90} (mm)	45
CU	1.5
Dry unit weight (kN/m^3)	3.67
Void ratio	2.19
Permeability (cm/s)[1,2]	15
Compression index[1]	0.79

Notes: (1) From large scale laboratory tests (Paranhos and Palmeira, 2003); (2) From large scale constant head permeability tests (Paranhos and Palmeira, 2003).

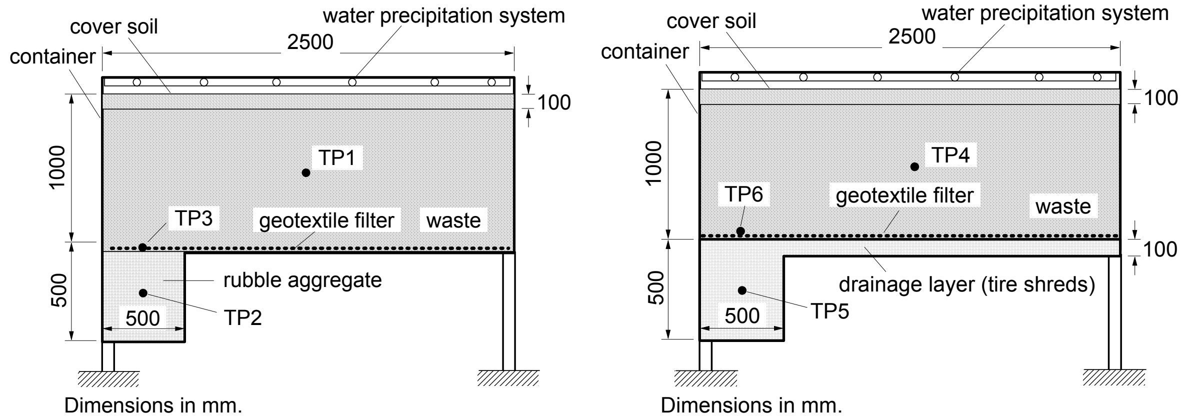
Table 3. Characteristics of the geotextile filter used in cell CT.

Mass per unit area (g/m^2)	150
Thickness (mm)	1.5
Normal permeability (cm/s)	0.4
Permitivitty (s^{-1})	2.5
Filtration opening size (mm)[1]	0.15

Notes: (1) Hydrodynamic sieving tests (CFGG 1986).

2.2 Waste Containers

Additional studies on the performance of alternative drainage materials were also conducted on a smaller scale basis using waste containers. Two containers (C1 and C2) were manufactured for this purpose and their general characteristics are schematically presented in Figure 2. The dimensions of the containers are 3.5m (length) x 2.5 (width) x 1.0 m (height). Along the largest side of the container there is a lateral trench that can be filled with the drainage material and which conducts the leachate to reservoirs adjacent to the containers. In the middle of the same side a 1.4m high glass window allows views of the drainage system during the tests. A set of perforated pipes at the container's top allowed water to be uniformly spread on the waste mass surface, simulating precipitation under controlled conditions. In container C1 the drainage system consisted only of the drainage trench filled with the rubble aggregate and a layer of



(a) Container C1. (b) Container C2.

Figure 2. Characteristics of the waste containers.

geotextile covering the entire plan area of the container (Fig. 2a). The drainage system in container C2 consisted of a 0.1m thick layer of tire shreds underlying a geotextile filter (Fig. 2b). In this case the lateral drainage trench was also filled with tire shreds. The geotextile filter used in both containers was a needle-punched non woven geotextile, made of polyester, 2.3mm thick and with a mass per unit area of 200g/m^2.

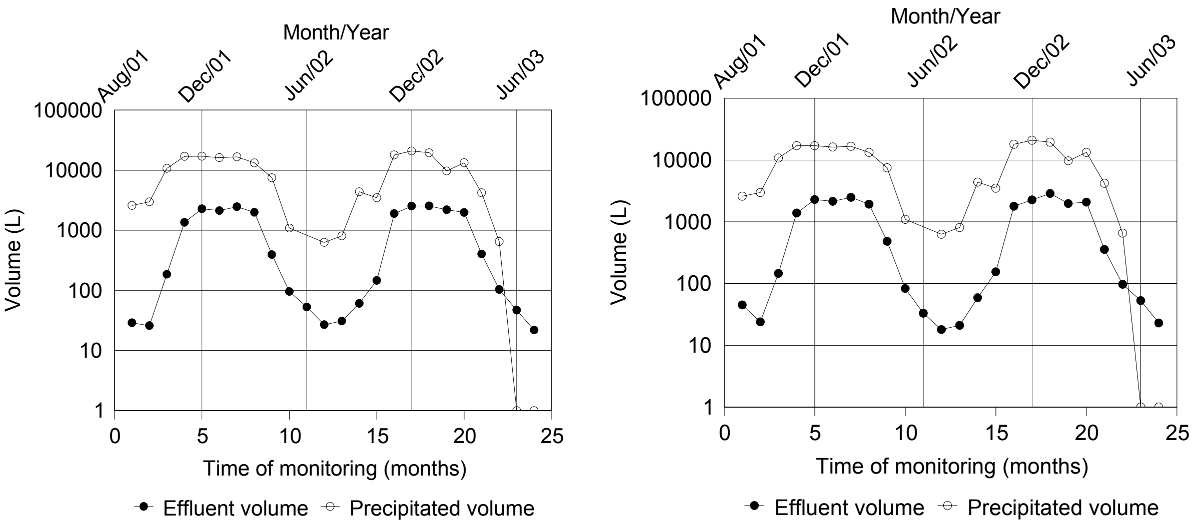
The domestic waste used in the containers was composed by: organic matter (44%), paper (16%), cardboard (10%), plastic (16%), metal (4%) and others (10%). The initial waste moisture content was equal to 58%. Initially, the total mass of waste to be disposed in the containers was mixed for homogenisation. Each container received approximately 2.5 tons of waste with an initial height of 0.9m. The waste was disposed in a loose state with an average mass per unit weight of 4 kN/m^3. A 0.1m thick clayey cover soil was placed on top of the waste layer. Seventy five days after waste disposal in the containers water started to be spread on the waste mass to increase its moisture content and favour biological activity. During wet seasons water intakes occurred at a rate of 10L/week while during dry season this rate was equal to 2.5L/week. Water was added to the waste mass in a single moistening stage each week. Instrumentation installed in the containers allowed the measurement of waste settlement, temperatures (temperature transducers) in the middle of the waste mass, below the geotextile filter and inside the drainage trench (TP1 to TP6 in Figs. 2a and b) as well as the measurement of leachate flow rate variations with time. Leachate samples were collected with time for chemical analysis such as pH, nitrate content, ammonium content, chemical oxygen demand, sulphate content and solids contents.

Additional information on materials and testing methodology can be found in Paranhos (2002), Silva (2004) and Palmeira et al. (2006).

3. RESULTS AND DISCUSSIONS

3.1 Experimental Waste Cells

Figure 3 shows the precipitated and effluent volumes for the experimental cells during the first two years of monitoring. The volume of leachate released from each cell is smaller than the precipitated volume due to runoff, evaporation and water retention in the waste mass. It should be noted that the dry and rainy seasons in the region run from May to September and from October to April, respectively. Those figures show that the effluent volumes were fundamentally dependent on the precipitation, being highly sensitive to variations in precipitated volumes.



(a) Cell CGR (b) Cell CT

Figure 3. Effluent and precipitated volumes in the experimental cells.

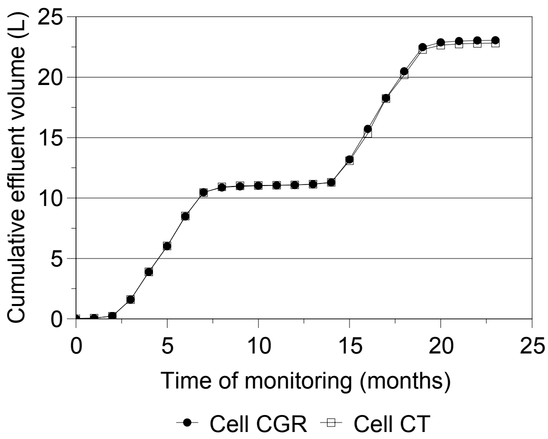


Figure 4. Cumulative effluent volume from the cells versus time.

Figure 4 shows the variation of cumulative effluent volume versus time for both cells. It can be noticed that the different drainage systems presented very similar behaviour, with the total amount of leachate liberated being almost the same for both cells.

The values of normalised settlements of the waste mass in the cells versus time are presented in Figure 5. The normalised settlement was calculated dividing the vertical settlement at the top of the waste mass by the initial waste thickness. The development of waste settlement in each cell is very similar. The precipitation on the cells along the monitoring period is also depicted in Figure 5. It can be noticed that a faster rate of waste settlement, as a result of greater waste degradation, takes place during the wet season, when infiltration of rain water in the cells is greater.

Figures 6(a) and (b) show results of chemical analyses carried out on the leachate liberated by the experimental cells in terms of pH and COD values versus time. Some differences between results from each cell can be observed and probably were due to waste variability. However, during most of the observation period and particularly at the end of the tests the results obtained for both cells were not significantly influenced by the type of drainage system used.

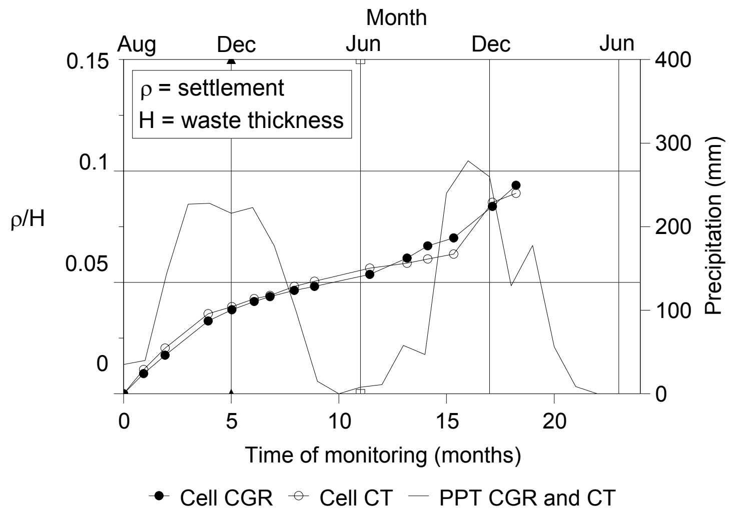
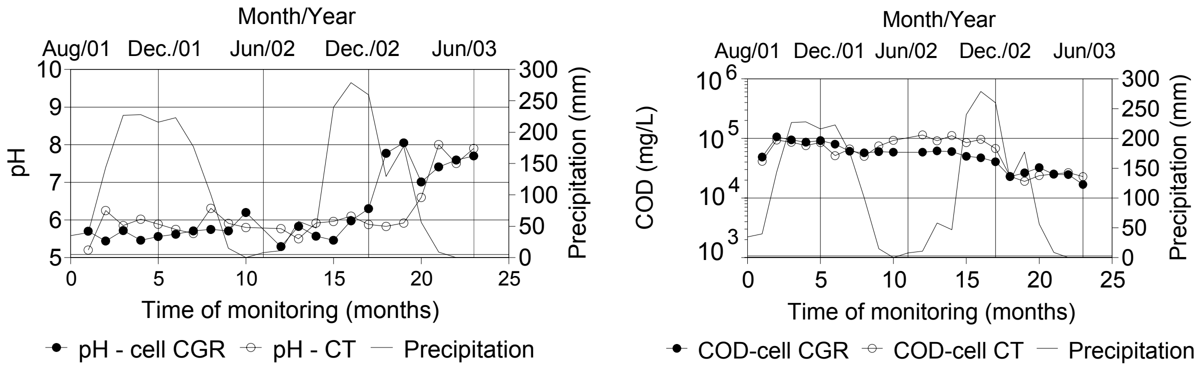


Figure 5. Normalised waste settlement against time.



(a) pH values against time.

(b) COD values against time.

Figure 6. Leachate pH and COD values versus time in the experimental cells.

3.2 Waste Containers

Figure 7 presents the variation of accumulated leachate volume versus time obtained in the tests with the waste containers. During the first stages of the tests when no water was added liberation of leachate was only observed for the system with the tire shreds (container C2). The lack of leachate liberation from container C1 was due to the relatively low transmissivity of the geotextile layer at its bottom, which delayed the flow of leachate towards the drainage trench, and to the field capacity of the rubble gravel. On the other hand, container C1 liberated leachate immediately with the cumulative volume of leachate tending to stabilisation 70 days after waste disposal. After precipitation has started both drainage systems responded immediately with rates of leachate liberation similar to the rate of water intake.

The variations of leachate chemical oxygen demand and pH with time are presented in Figures 8(a) and (b). The rate of precipitation with time during the testing period is also shown in this figure. The COD values obtained for the leachate from C1 was considerably smaller than those obtained for the leachate from C2. This difference can be a result of factors such as interaction between drainage material and leachate, better filtering action of the rubble aggregate and the delay in the liberation of the leachate by the aggregate drain in comparison to the tire shreds drain. These COD results are consistent with those obtained in the tests with the experimental cells. Some low levels of degradation were visually observed in the rubble grains after the tests. An initial pH value of 8.5 of the leachate from C1 can be observed, which is likely to be a consequence of the interaction of the leachate and the concrete particles of the drainage system of this container. It should be pointed out that a pH value of 8.7 was observed in tests with aggregate particles submerged in clean water. As time passed, the values of pH of the leachate from C1 dropped ending at a value close to 7 (neutral condition). This continuous reduction in pH can be a result of the aggregate particles having been covered by a film of leachate which minimised the direct interaction between concrete and leachate. pH values started within the acid range (between 5 and 6) in the early stages of the test in container C2 and also ended close to the neutral value.

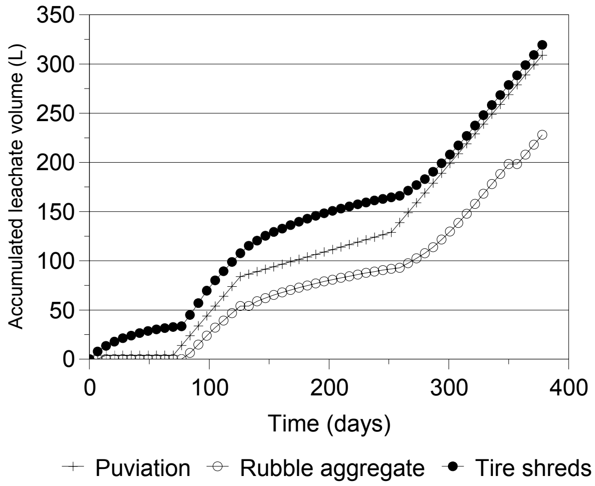


Figure 7. Accumulated leachate volume against time – waste containers.

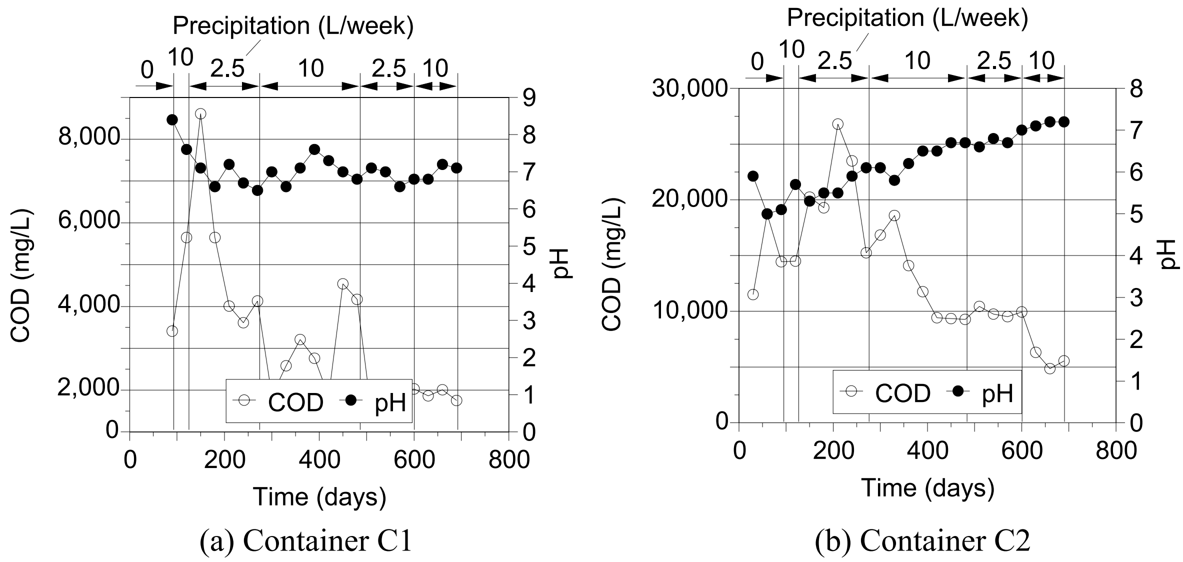


Figure 8. COD and pH values with time – waste containers

4. CONCLUSIONS

This paper investigated the use of alternative drainage materials in combination with geotextile filters in drainage systems of waste disposal areas. The main conclusions obtained are summarised as follows.

In general, the performance of the experimental cells was not significantly affected by the type of materials used in the drainage systems (natural gravel or tires) for the duration of the tests. The results obtained showed the potentials of using alternative materials in drainage systems of waste disposal areas.

The tests with the waste containers showed that some properties of the leachate were affected by the type of material (rubble aggregate or tire shreds) used in the drainage system. Some low levels of degradation were observed in the rubble aggregate grains due to the reaction with the leachate.

The geotextile filters used functioned well in the waste cells and waste containers, showing no signs of clogging during the monitoring period. The test results showed that the alternative materials tested may provide good substitutes for conventional natural granular materials. However, further investigations are required to better assess the long term behaviour of these materials under hazardous working conditions.

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