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CLOGGING TEST OF LANDFILL LEACHATE DRAINAGE USING DIFFERENT FILLERS

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Abstract. Municipal waste landfill leachate formed at different stages of the operation of the landfill, has a negative impact on the natural environment. According to the newly implemented waste management policy on modern solid waste deposit sites, landfill leachate has to be monitored. Five experimental columns were constructed in size of 500 mm long and 200 mm in diameter. They were filled with different fillers. The flow of leachate allowed for calculation of the leachate volume per year in a landfill, where it was taken. The experiment was carried out for 365 days. Significant change of the porosity was determined in all columns. Although the landfill for this period represents only 1/50 or less of the operation time, the laboratory tests found that the drainage layer bandwidth of reduction in one year can have a negative impact in the long run of time, which will only increase congestion. For higher porosity value of the test substance, allowing for more impairment, a 2% points decrease in the value is less dangerous when the porosity value is of 57 or 45 percent, than of 29 or 47%. The main elements that influence the conductivity decrease are calcium, silicon and iron compounds. The change of these compounds was observed during lysimetric study, where the concentration of each month in all the columns was decreasing. The results showed, that the rubber used for creating fillers in columns provided for bigger porosity of the layer. It is the beneficial reason to use rubble and rubber waste mix for forming drainage layer in landfills.

Keywords: drainage layer, landfill, leachate, porosity.

1. Introduction

Modern municipal waste landfills have started to operate in Lithuania since 2007. Earlier practice was to dump the municipal waste in landfills, which were not equipped with leachate and gas collection systems, and therefore leachate and gas find their way into the surrounding environment (Alkalay *et al*. 1998; Zigmontienė, Zuokaitė 2010; Petraitis 2009; Jaskelevičius, Lynikienė 2009).

New engineered sanitary landfills have been designed with leachate collection systems consisting of perforated PVC pipes laid down in granular drainable layer. This layer receives and filters the leachate formed through the waste resulting from precipitation of atmosphere. The leachate composition depends on the type of waste in the landfill, waste age, ongoing processes of decay and weather conditions. The rainfall infiltrates and percolates through household waste, which results in contamination with organic and inorganic compounds (El-Fadel *et al*. 2002; Ettler *et al*. 2008; Armstrong, Rowe 1999).

The most important function of a drainage layer in a municipal waste landfill is to facilitate collection and remove leachate (moisture passing through the waste). The leachate, of multi component composition in contact with the drainage particles, reduces pore size after a long time (Ramke 2009). Clogging in the municipal waste landfill leachate collection system is due to the accumulation of deposits in the drainage layer resulting from various physical, chemical and biological processes in the landfill (McIsaac, Rowe 2008). The amount of increasing accumulated material cement the individual particles of drainage layer and it becomes less permeable for the leachate. Laboratory tests are important in order to determine the composition of the leachate, thereby determining chemical elements that are mainly involved in the process of clogging. Currently, many efforts are being made to find the optimum solution to reduce the drainage layer of pollution without increasing costs, while having no negative impact on the natural environment.

Fleming *et al.* (1999) reported the chemical composition of the clog material (dry mass) averaged about 21% of calcium, 34% of carbonate, 16% of silica, 8% of iron, and 1% of magnesium based on a study on the Keele Valley Landfill in Maple, Ontario, Canada. Field studies conducted at numerous German landfills showed that the drainage material within the leachate collection system can become filled with incrustations, resulting in a decrease in the void volume and causing clogging (Brune *et al*. 1991). The chemical composition of the clog solids of the German landfill study was of about 20% of calcium, 30% of carbonate, 21% of silica, 2% of iron, and 5% of magnesium and 22% of others on a dry mass basis. The chemical composition of the clog material (dry mass) averaged as similar as the Keele Valley landfill, that is why it is important to study more about these elements and their changes in leachate (Fleming, Rowe 2004).

Laboratory and field studies (McIsaac *et al*. 2000; Van Gulck *et al*. 2003; McIsaac, Rowe 2005) showed that most pairs of polluting material consist of iron, silicon, calcium compounds in large quantities. Although the combinations of these elements themselves are not harmful, they create dangerous conditions, especially for heavy metals, which can spread in the environment.

Rowe *et al.* (2002) documented the findings from the early stages of ongoing investigation. They observed a decrease in calcium concentration in the leachate between the influent and effluent. They also noted a linear relationship between the total COD and dissolved calcium in both the raw leachate feedstock and partially treated leachate effluent from the laboratory reactors. Rittmann *et al.* (1996) described the chemistry of these reactors and the implications for combined clogging based on pretreatment of the leachate.

The main objective of this study was to evaluate the effect of different materials of the drainage layer on the composition of the leachate and porosity for a period of twelve months.

2. Materials and Methods

During 15 years scientists have made researches on drainage layer clogging. The best way to perform an experiment is to do a column test. The experimental set up (Fig. 1) consisted of five columns made up of polyvinyl chloride (PVC) plastic pipe each having a diameter of 200 mm and depth of 500 mm. Each column was filled with different drainage layer and leachate was allowed to drain at the above mentioned flow rate. The drainage layers were supported by wire mesh having 2 mm opening.

In order to evaluate leachate composition change dependence on the drainage layer, leachate at the rate of 0.2 m/m/day rate was passed through the drainage layer based on optimal flow velocity of leachate in the landfills (Van Gluck, Rowe 2004). The process of clogging is slower at higher rate of percolating leachate and vice versa, but the average blockage is formed over a long period of time.

Fig. 2 shows the samples of drainage layers used for the experiments. Different fillers formulated from graded gravel, alluvial rubble (particle size 32–45), rubber waste and asphalt waste (particle sizes 35–45 mm) were used for drainage. Sieved gravel (a) was in line with the requirement of 35–62 mm size fraction recommended for landfill drainable layer (Rowe *et al*. 2002; Hudson *et al.* 2003; Hudson *et al*. 2009; Warith *et al.* 2004).

Rubber residues crushed to 30–60 mm size were mixed with gravel and rubble at the ratio of 1:3 based on experimental trials by McIsaak and Rowe (2005). Asphalt waste was also used and mixed with rubble as a cost effective choice.

Table 1 shows the density and porosity of drainage layer material. Density is needed to calculate the porosity. The porosity is high for the rubble mixed with rubber waste and asphalt waste. The rubber waste increases porosity by 20% compared to the rubble. Asphalt waste also increases porosity by 7%. The rubber and asphalt materials are making layer more permeable and useful for drainage material. Also, it is useful for recycling rubber and asphalt material.

Fig. 1. Experimental set up

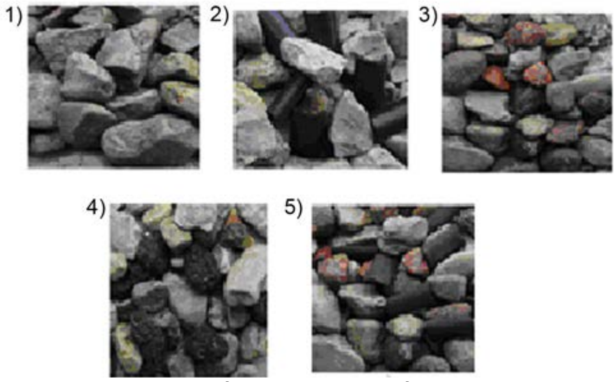

Fig. 2. Materials used for drainage layer filler: 1 – the drainage rubble), 2 – rubble mixed with rubber waste, 3 – sieved gravel (35–62 mm size), 4 – rubble mixed with asphalt waste, 5 – gravel mixed with rubber waste

Table 1. Porosity of columns fillers

Filler	Porosity%
Rubble of drainage	37
Rubble of 70% mixed with rubber waste of 30%	57
Sieved gravel(35 – 62 mm size)	29
Rubble of 70% mixed with asphalt waste of 30%	45
Gravel of 70% mixed with rubber waste of 30%	33

Drainage layer porosity is determined using an appropriate methodology similar to that of the soil layer. The drainable layer consists of different size voids through which leachate drains out. The total of all the spaces and pores between the particles in the drainage capacity of the drainage unit volume is called porosity.

Drainage layer porosity (P) is calculated using the drainage density and particle density and is expressed as a percentage by volume:

$$P(\%) = (1 - S_t/S)\times 100,$$

P – porosity%, S_t – density of layer , g/cm^3; S – density of layer particle g/cm^3.

For the evaluation of porosity it is important to assess the drainage layer. The porosity of drainage layer changes due to its contamination and deposition of some ions. The porosity of all the fillers were measured and calculated before and after the experiment.

Two methods were used to measure leachate parameters concentration: calcium is determined by titration method, while the silicon and iron by photometric method.

Setting concentration changes were calculated by correlation dependence between the different porosity and concentration. Calculating the correlation dependence it was accessed how more pairs of points affect the changes of leachate element concentration, because both calcium and silicon are mainly accumulated on the surfaces in contact with them.

3. Results and Discussion

In order to identify the different layers of materials making an impact on the clogging of drainage layer, this section provides the leachate characteristics and porosity change depending on material. Significant changes in all measured Vilnius municipal landfill leachate parameters occurred over the duration of the experiment, and the composition of the leachate changed significantly after about 365 days of operation.

It is important to analyze qualitative parameters of the leachate composition change as clogging progresses. Silicon, calcium and iron are the elements examined in this study to evaluate possible changes in the drainage layer. In studies with finer fractions materials, it was observed that the bandwidth reduction in drainage layer is up to 15% per year (Van Gluck *et al.* 2003; Cardoso *et al*. 2006).

Taking into account the results obtained with the different drainage layers, the minimum change for silicon concentration in the leachate quality was observed for the columns filled with rubble, rubble and rubber waste and with gravel and rubber waste mix. For these three materials, the amount of silicon in leachate during the test period of 12 months decreased by about 2 mg/L (see Fig. 3). It is 5% of silicon concentration of the raw leachate, but knowing that this affects the placement in a short period of time, one can decide about the future decrease in drainage layer permeability (Van Gulck, Rowe 2004). It is important to make long-term studies of clogging for the exact know of silica concentration changes in leachate. Depletion of higher concentrations is observed at baseline and after six months the content of the element varies only in 1–3 mg/L. The decreasing trend shows the influence of material used for the drainage layer. The highest decrease of silicon volume is in column filled with gravel, as one of the main causes include gravel components: gravel composed of granite and rock, as well as calcareous rocks. The latter (McIsack *et al.* 2000) often leads to drainage of the rock layer clogging instability. Sand layer is often used to protect waste from the wind, wild birds or animals. The rain and snow melt water migrates through the waste to the drainage layer and transport part of sand particles to drainage layer.

The changes in leachate calcium, silicon and iron between the influent and effluent of the column are shown in Figs 3, 4 and 5. Fig. 3 presents the results of change in silicon content of the leachate. The maximum decrease was in the column filled with gravel mixed with rubber, from 33.9 mg/L to 30.3 mg/L. The minimum decrease was in column filled with rubble, from 33.9 mg/L to 31.7 mg/L. These results show that rubble used in landfill is chosen correctly. Although the quantities of silicon are not provided in the standards of clearly fresh water or sewage and the element itself is not dangerous for the environment, it has a negative impact on drainage, which clogs the pores and reduces permeability.

Fig. 4 presents the results of change in calcium content of the leachate. In the second and fifth columns calcium concentration decreased slightly by about 2%, from 454 mg/L to 444 mg/L, while the other columns show a change by about 4%. The maximum decrease was observed in the column with gravel mixed with rubber. There has been a decrease from 454 mg/L to 420 mg/L during the test time.

Iron is one of the elements that is found in clog material. During the test period its concentration decreased all the time, especially in the column filled with gravel and rubber mix (Fig. 5).

It is very important to analyse the dependence of porosity on changes of concentration. Correlation coeficient was calculated between porosity of material and changes of analyzed concentrations of elements. Fig. 6 shows the amount of decrease in calcium concentration that has a high influence on porosity of the drainage layer.

Porosity is more affected by the changes in calcium concentration than by silicon (Fig. 7). A lower value of correlation coefficient (Fig. 8) suggests that change in iron content of the leachate has no relation to the porosity of the drainage layer.

The chemical composition of leachates from lysimeter study was within the range of reported values for landfill leachate. Although leachate composition was very widely depending on moisture content, age of landfill, nature of the wastes, and the events that preceded the time of sampling (Alkalay *et al.* 1998; Paksy *et al*. 1998), laboratory lysimeters provided an effective model system for study of the reactions that might impact clogging of leachate collection systems. In addition to the differences in the amount of moisture available for waste degradation and landfill age, different temperature ranges are associated with a biologically active landfill in comparison with the laboratory environment.

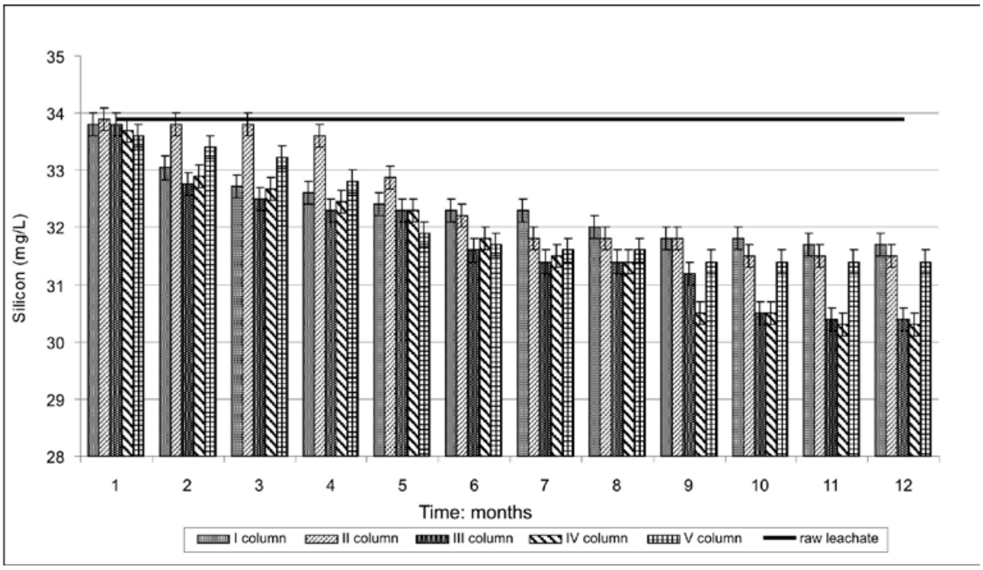

Fig. 3. Change of silicon concentration in the leachate. Fillers of columns: 1st column – rubble; 2nd column – rubble mixed with rubber; 3rd column – gravel; 4th column – rubble mixed with asphalt; 5th column – gravel mixed with rubber

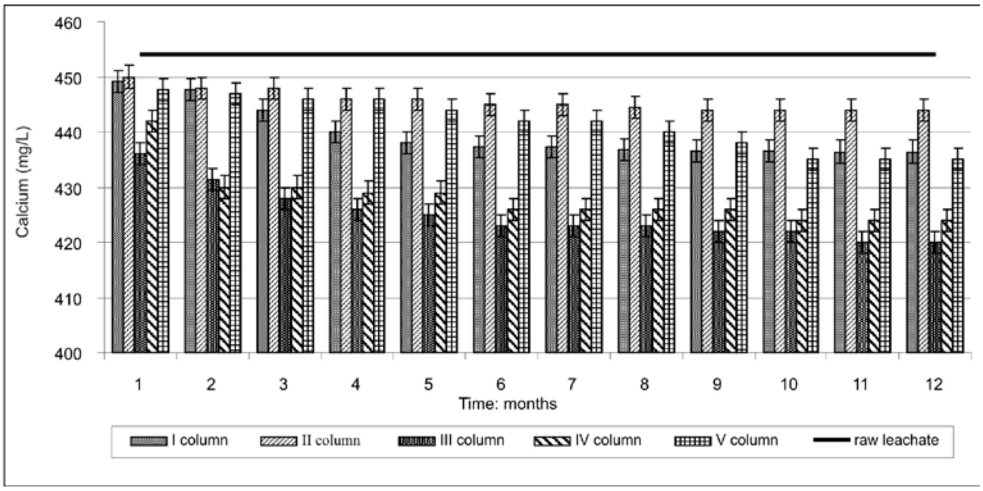

Fig. 4. Changes of amount of calcium concentration in leachate. Fillers of columns: 1st column – rubble; 2nd column – rubble mix with rubber; 3rd – gravel; 4th column – rubble mix with asphalt; 5th column – gravel mix with rubber

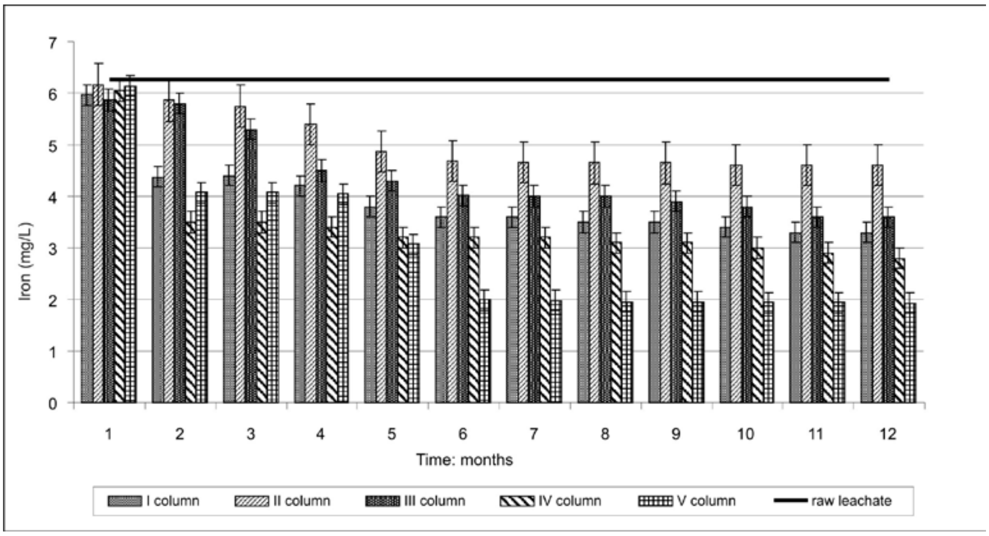

Fig. 5. Changes of amount of iron concentration in leachate. Fillers of columns: 1st column – rubble; 2nd column – rubble mix with rubber; 3rd – gravel; 4th column – rubble mix with asphalt; 5th column – gravel mix with rubber

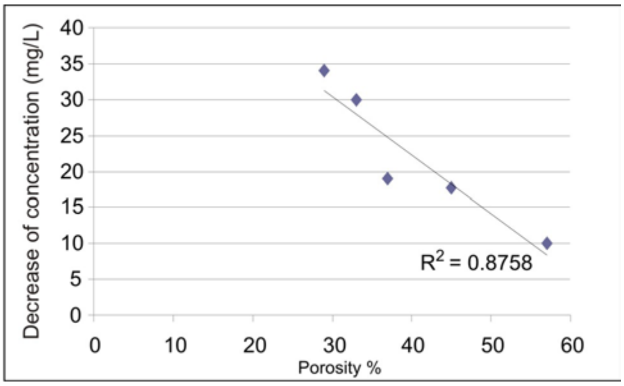

Fig. 6. Correlation between a change of calcium concentration in leachate and porosity of drainage layer.

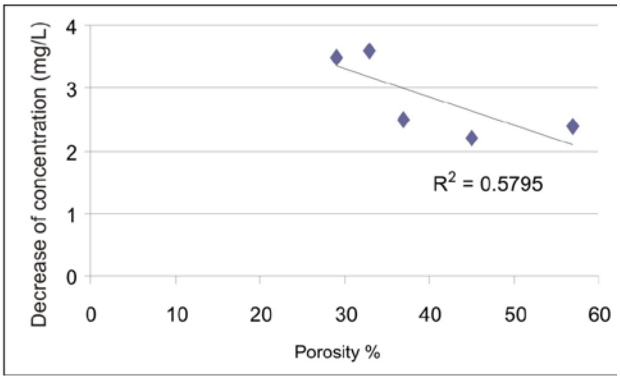

Fig. 7. Correlation between a change of silicon concentration in leachate and porosity of drainage layer

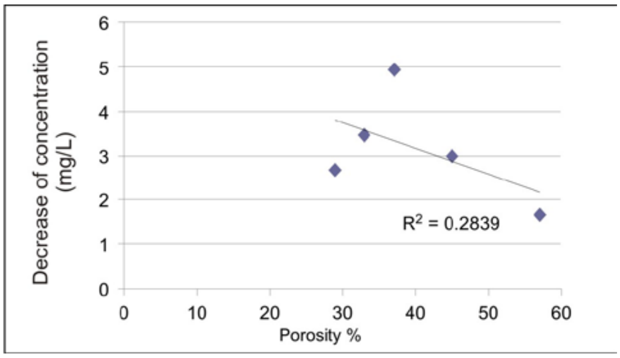

Fig. 8. Correlation between iron concentration and porosity of drainage layer

4. Conclusions

1. The findings indicated that drainage layers with rubber waste are more susceptible to chemical and biological clogging than without them. Calcium, silicon and iron content of the leachate are good indicators of clogging of landfill drainage layer.

2. The decrease in calcium concentration is found to have a good correlation with the porosity of drainage layer.

3. It was discovered that the best for porosity is rubble and landfill waste rubber blend – 57%. The rubber waste increases the porosity by 20%, from 37% to 57%.

4. In the study the rubber and asphalt waste used for drainage filler increased porosity more, from 8% to 20%. These two materials should be useful for forming drainage layers in landfills. Bigger porous holes between solid particles make the higher percent of porosity.

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SKIRTINGŲ UŽPILDŲ TINKAMUMO, SIEKIANT IŠVENGTI FILTRATO DRENAŽO UŽSIKIMŠIMO, TYRIMAS

K. Bazienė, S. Vasarevičius, A. A. Siddiqui

Santrauka

Komunalinių atliekų sąvartynų filtratas, susiformuojantis skirtingais sąvartyno eksploatacijos etapais, daro neigiamą įtaką gamtinei aplinkai. Naujai įgyvendinama atliekų tvarkymo strategija. Šiuolaikinėse kietųjų atliekų deponavimo aikštelėse atliekama sąvartynų filtrato stebėsena. Eksperimentui atlikti sumontuotos 500 mm ilgio ir 200 mm skersmens kolonėlės buvo pripildytos skirtingų užpildų. Filtratas leistas apskaičiavus metinį sąvartyno filtro kiekį. Eksperimentas buvo atliekamas 365 dienas. Reikšmingi poringumo pokyčiai nustatyti visuose tirti naudotuose mišiniuose. Sąvartyno eksploatavimo atžvilgiu toks laikotarpis tėra 1/50 dalis ar dar mažiau eksploatavimo trukmės. Laboratoriniais tyrimais nustačius, kad drenažo sluoksnio pralaidumo sumažėjimas per vienerius metus gali turėti neigiamos įtakos, yra akivaizdu – per ilgą eksploatavimo laiką užsikimšimas tik didės. Kai tiriamos medžiagos poringumo vertė didesnė, leistinas didesnis jos sumažėjimas, t. y. poringumo vertei esant 57 ir 45 %, jos sumažėjimas 2 % punktais yra mažiau pavojingas nei esant 29 ar 47 %. Pagrindiniai elementai, darantys įtaką laidumo sumažėjimui, yra kalcio, silicio bei geležies junginiai. Šių junginių koncentracijų pokytis buvo stebimas lizimetrinio tyrimo metu. Koncentracijos kiekvieną mėnesį visose kolonėlėse mažėjo. Rezultatai rodė, kad sąvartynų filtrato drenažiniam sluoksniui tinkamiausia naudoti drenažo skaldos ir gumos atliekų mišinį. Jo poringumas mažiausiai pakito.

Reikšminiai žodžiai: drenažo sluoksnis, filtratas, poringumas, sąvartynai.

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