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ANALYSIS OF A MUNICIPAL LANDFILL DRAINAGE LAYER USING TYRE SHREDS AND RUBBLE

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Abstract. Municipal waste landfill leachate is formed at different stages of landfill operation and has a negative impact on a natural environment. According to the recently implemented waste management policy, landfill leachate in modern solid waste disposal sites has been monitored. Due to a complex composition of components for filtrate, over a long period of time, the processes of commutation in a drainable layer have been taking place, thereby reducing the porosity and permeability of the layer. Calcium, silicon and iron compounds are the main elements influencing a decrease in conductivity. Filtrate has formed in landfills and waste water and involved the process of precipitation percolating through waste. For 3 months, studies on two different drainage layers of filtration have been carried out. The obtained results have showed that for forming the landfill leachate drainage layer, a drainage rubble layer of 40% mixed with counter rubber waste can be successfully used.

Keywords: municipal waste landfill, leachate, drainage layer, waste, tyre shreds.

Introduction

Waste management is one of the main discussed issues worldwide, including Lithuania. Landfilling is the most common method for disposing municipal waste. While this is not the best way to manage waste, however, it still remains the most popular and frequently used method employed by the developed countries like Canada, England, etc. In order to effectively solve this problem, the use of as many recycling materials as possible is an important point. Glass, paper, plastic and other kinds of waste are widely used for recycling throughout the world. The use of tyre shreds applied for the formation of a landfill drainage layer is one of the options widely studied by the scientists from Canada, United Kingdom and Germany. In recent years, tyre shreds applied for landfill drainage have been given global attention. Nevertheless, uncertainty regarding drainage layers formed of tyre shreds remains a relevant question. Fleming & Rowe (2004) and Paksy *et al*. (1995) evaluated the reasons for clogging the drainage layer with chemically and biologically mediated deposits. However, the process of how the clogging of biological and chemical origin is taking place using waste materials in landfills still have not been properly investigated to have an adequate answer.

It is considered to be both environmentally and economically beneficial to using tyre shreds as landfill drainage material. Water that percolates through waste from precipitation, irrigation and waste biodegradation leaches contaminants from refuse thus generating a fluid called leachate. The composition of the mass of waste affects the composition of leachate. Field studies on leachate collection systems (Fleming *et al.* 1999) have showed that clogging of drainage and filter materials occur due to the accumulation of material within the pore space of drainage media resulting in a decrease in porosity and hydraulic conductivity. Several researches have approved the suitability of tyres as landfill drainage material (Hudson *et al*. 2003; Van Gulck, Rowe 2004; Paksy *et al.* 1995; Vasarevičius *et al*. 2005). However, these tests are usually conducted for short periods of time using water or methanogenic leachate. However, the chemical and biological composition of leachate that passes through the leachate collection system combined with the presence of microbial activity result in chemically and biologically induced clogging (Fleming *et al.* 1999). The development of clogging decreases pore space available for transmitting leachate, reduces the hydraulic conductivity of the drainage layer and consequently reduces the efficiency and period of effective functioning of the leachate collection system. Since these systems may be required to collect and remove leachate for the extended periods of time, it is important to design them with optimum long – term performance and service life. Fleming and Rowe (2004), Paksy *et al*. (1995) made lab tests on chemical and biological clogging of drainage layers that might occur during the lifetime of landfill. Research conducted in Canada indicates that tyre shreds are more susceptible than gravel for clogging and will not be as effective as drainage layers after a relatively short time.

The history of studies on landfill design highlights the main problems encountered during the operation of landfill. The complex composition of leachate clogs the landfill processes of the drainage layer. Clogging can be a possible result of landslides, washings and other negative processes affecting the natural environment. Currently, the landfill drainage layer is used for forming the rubble of 32–65 mm in diameter.

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

The landfill drainage layer is required as an additional filter, which helps with reducing risk in surrounding landfill. One of the widely concerned problems dealing with the drainage layer is forming recyclable materials (Ettler *et al*. 2008; Morgan *et al*. 1991). Construction waste is not applied for the drainage layer, because a high content of calcium carbonate in the filtrate of waste increases the possibility of clogging processes.

The researches performed by foreign scientists show that calcium carbonate, silica and iron compounds dominate in the clogging process (El-Fadel *et al*. 2002; McIsaac, Rowe 2005; McIsaak *et al*. 2000; Tatsi, Zouboulis 2002; Zigmontiene, Zuokaite 2010). The material forming a drainage layer must be made of appropriate matter and meet requirements for pressure. A pressure of 200 kPa for the drainage layer of 20 meters of waste mass (Hudson *et al.* 2003) can be observed. However, material fractions less than 32 mm in diameter as small clogging particles cannot be used. The particle size of tyre shreds making the fractions of 50 mm – 100 mm are used for forming landfill drainage. The main objectives of this study include:

- analysis of changes in the concentration of calcium, silicon and iron in leachate and their dependence on the composition of the drainage layer;
- evaluation of an aggregated impact of different drainage layers on the clogged landfill drainage layer.

Material and Methodology

The biggest regional landfill is situated in Kazokiškės district close to Vilnius city. This place conforms to the EU regulations (Fig. 1). Vilnius is the biggest city in Lithuania and has the population of more than 600,000 inhabitants. Waste from the whole region goes to Kazokiškės landfill making up to 20,000 t/ a month. Leachate for the performed experiment was taken primarily from this landfill operating from 2007. Leachate was very concentrated, made of different compounds and had a high effect on clogging processes. The effect of rainwater on a dissolving waste layer occurs when humidity reaches 45%, which in practice means that 13,5 cm of water/meter waste is absorbed before the formation of leachate and depends on the initial humidity of landfill waste (Tatsi, Zouboulis 2002).

An experimental stand (Fig. 2) was mounted in a polyvinyl chloride (PVC) plastic pipe having the diameter of 200 mm and a length of 500 mm. The bottom of the drainage layer has a support grid with a pore diameter of 2 mm. The whole column of a filled drainage layer stands on both sides of the tightly closed container. The process of the inflow and outflow of filtrate takes place in pipes. The laboratory test was made applying two different drainage layers.

Laboratory column tests were carried out to evaluate clogging under controlled conditions. The drainage layer is formed of three parts: a) column 1 is made of 30% of drainage rubble, 40% of tyre shreds and 30% of drainage rubble, b) column 2 – of 35% of drainage rubble, 30% of tyre shreds and 35% of drainage.

Fig. 1. Geographical position of Kazokiškės landfill, the place where a sample of leachate has been taken.

The porosity of a drainage layer is determined using an appropriate methodology calculating the porosity of the soil layer. The particles of granulated material are not in touch with one another – they get into contact only at certain points. As a result, the drainage layer consists of a different size of voids and gaps that allow filtrating leachate. Porosity is the total volume of all space and pores between the particles in the drainage capacity of the drainage unit volume. There is more space for leachate movement filling drainage in case it has a higher level of porosity.

Fig. 2. Experimental stand with different filling: a) 40% of tyre shreds and 60% of drainage rubble, b) 30% of tyre shreds and 70% of drainage rubble

A column test was carried out to monitor changes in the composition of leachate and to temporally quantify clogging. The samples of leachate were monthly tested before the influent and after the effluent valve. The samples were examined to obtain the concentrations of calcium, silicon and iron. The tests were performed to follow changes in the porosity of the drainage layer and variations in void volume, because the drainage layer becomes frequently clogged.

Drainage porosity will be lower than the actual porosity as a result of incomplete draining of leachate under gravity due to the fluid adhering to drainage medium and clog material (McIsaac, Rowe 2008). Drainage porosity was measured before and after the conducted column test.

The porosity of the drainage layer (P) is calculated knowing drainage density and particle density and is expressed as a percentage by volume:

$$P = (1\text{-}St/S)\times 100,$$

P – porosity; St – drainage density; S – particle density.

It depends on the solid phase density of soil (more precisely, minerals and organic substances that form a part of hard soil, the nature of soil, fluffy dense structure). It is necessary to determine the structure of soil, aeration porosity, water capacity and moisture regime and to assess the overall soil porosity. An important point is the evaluation of the porosity of the drainage layer in the study on clogging, because accumulation on the porous media causes changes in the conductivity of the drainage layer. Thus, a possibility of judging about the level of clogging arises. In case of high porosity, soil aeration is good enough and moisture cannot accumulate, because precipitation over large space quickly runs off into collection pipes.

Qualitative Parameters of Data on Leachate

The performed experiment suggested changes in the concentrations of silicon, calcium and iron found in leachate. Changes occurring in these elements allow dealing with variations in the porosity of the drainage layer. Studies on smaller granular materials indicate that conductivity in the drainage layer is annually reduced by 15% (Van Gulck *et al.* 2003). Smaller pores (lower porosity) between particles produce more conductive conditions for clogging. Therefore, a lower percent of porosity causes lower conductivity in the layer.

The porosity of the created layer was measured before starting a test on clogging. The porosity of drainage rubble was 37% and that of tyre shreds – 58% (Table 1). Different porosity of each layer was measured. Some Canadian scientists (McIsaac, Rowe 2008) established that clogging processes started from the top zone of all columns.

Table 1. Porosity of different layers

Material	Before test (%)	Following 90 days from the test (%)	
		Column 1	Column 2
Drainage rubble at the top of column	37	35	35
Layer of tyre shreds	58	57	58
Drainage rubble at the end of the column	37	36	36

Municipal landfill leachate is rich in large quantities of various substances on contact with the drainage layer deposited on particle surface that causes clogging. Tyre shreds used for layers increase porosity and hence reduce the possibility of clogging. Although tyres are at a high pressure of 200 kPa (Hudson *et al.* 2008), still, it is not sufficient. When hydraulic conductivity is 0.3 m/s, slower congestion takes place. An increase in the amount of tyre shreds leads to higher compression. For forming a drainage layer, Canadian researchers (McIsaac, Rowe 2005) propose using a part of tyres making less than 40%. British scientist Hudson (2003) investigated tyre shreds of different sizes. His studies showed that the application of tyre shreds caused no obstruction and was very suitable material for the use of formatting the landfill drainage layer (Hudson *et al.* 2003).

Field and laboratory studies (Fleming *et al.* 1999; McIsaac, Rowe 2005, 2008) disclosed that clogging solids contained high proportions of Ca and CO^{2-} constituents. Colloidal chemistry studies on landfill leachate (Van Gulck *et al.* 2003) revealed that calcium could be presented both in a dissolved and colloidal form. Thus, a fraction of TSS may contain calcium bearing minerals suspended in leachate and/or calcium bound to suspended solids.

Additionally, calcium is probably a constituent of extracellular polysaccharides and/or proteins used as linking materials for the granulation of microorganisms (Morgan *et al.* 1991; Yu *et al.* 2001). Thus, flocks of biomass may contain some calcium. Studies on geochemical modelling reported calcite and dolomite to be supersaturated in landfill leachate (McIsaak, Rowe 2008) and indicated that the precipitation of Ca^{2+} could occur and that the dissolution of bound calcium from suspended solids were not a favourable reaction.

The observations of lysimeter tests display the process of how the layer of tyre shreds is clogged and point out the main parameters determining changes.

The content of silicon very little changed for the period of the conducted investigations and varied from 33.9 mg/L to 33.1 mg/L in column (a) for the period of three months. The concentration of silicon in column (b) caused more extensive changes than in column (a) and made from 33.9 mg/L to 32.8 mg/L. Fig. 3 shows the downward trend to the concentration of silicon that could make effect on wider space between particles or different positions of tyre shreds.

Changes in silicon concentration made 0.2 mg/L (0.5% of the total amount) and changes in calcium concentration were 5 mg/L (1% of the total amount) for the period of three months. The obtained data show that calcium was affected more significantly. Comparing the amount of these two elements in leachate, changes in calcium were not that high as those in silicon due to the fact that the amount of calcium concentration was 10 times larger than that of silicon (Fig. 4).

The situation describing changes in the concentration of iron is different. The amount of iron concentration (Fig. 5) decreased by 0.2 mg/L for the period of three months while iron concentration in leachate was only 6.4 mg/L, which made 3% of the total amount. These are the major changes taking into account all investigated elements.

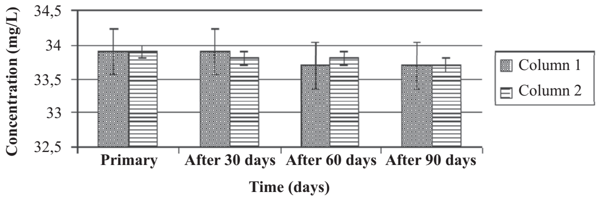

Fig. 3. Changes in the amount of silicon in leachate for the period of three months presented in two different columns (column 1 filled with 40% of tyre shreds; column 2 filled with 30% of tyre shreds)

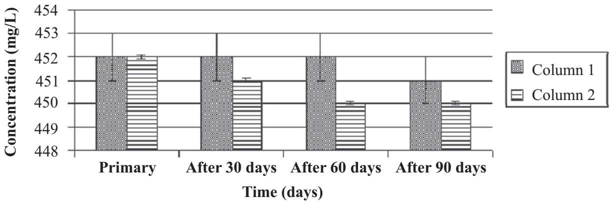

Fig. 4. Changes in the amount of calcium in leachate for the period of three months presented in two different columns (column 1 filled with 40% of tyre shreds; column 2 filled with 30% of tyre shreds)

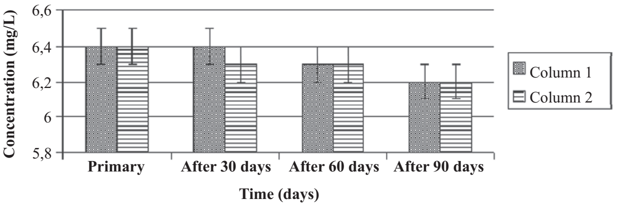

Fig. 5. Changes in the amount of iron in leachate for the period of three months presented in two different columns (column 1 filled with 40% of tyre shreds; column 2 filled with 30% of tyre shreds)

Conclusions

1. The selected drainage layer was formed from material considering the degree of porosity. A column of a drainage layer filled with different materials (layers composed of gravel and tyre shreds) precisely corresponds to the following requirements: removed excessive moisture, protection from flooding, washing.
2. The study on the concentration of leachate elements and porosity shows a decrease in the conductivity of the drainage layer. More significant changes in the composition of leachate can be observed when the column contains 50% of tyre shreds, which only indicates that the landfill drainage layer must be composed of less than 50% of tyre shreds.
3. The conducted research shows that the column volume filled with 40% of tyre shreds have an impact on the amount of Si, Ca and Fe concentrations found in leachate. It can be assumed, that tyre shreds in the landfill drainage layer affect the clogging process.

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SĄVARTYNO DRENAŽO SLUOKSNIO UŽSIKIMŠIMO TYRIMAS NAUDOJANT SMULKINTAS PADANGAS IR SKALDĄ

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Santrauka

Komunalinių atliekų sąvartynų filtratas susidaro sąvartyno eksploatacijos skirtingose stadijose ir turi neigiamą poveikį gamtinei aplinkai. Dėl sudėtingos komponentinės filtrato sudėties ilgą laiką drenažiniame sluoksnyje formuojasi kolmatacijos procesai. Pagrindiniai elementai, turintys įtakos laidumo sumažėjimui, yra kalcio, silicio ir geležies junginiai. Tyrimai buvo atliekami su dviem skirtingais kolonėlių užpildais, suformuotais iš drenažo skaldos ir smulkintų padangų sluoksnių, per kuriuos filtruojamas filtratas 3 mėnesius. Rezultatai parodė, kad sąvartynų filtrato drenažo sluoksniui formuoti tinka naudoti smulkintą padangų sluoksnį, sudarantį 40 % viso sluoksnio tūrio.

Reikšminiai žodžiai: atliekos, drenažo sluoksnis, filtratas, komunalinės sąvartyno atliekos, smulkintos padangos.