

EFFECT OF PRECIPITATION ON LEACHATE PARAMETERS CAUSING COLMATATION OF LANDFILL DRAINAGE LAYER

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Abstract. Municipal waste landfill drainage formatted at different stages of landfill exploitation, has a negative impact on natural environment. According to the newly implemented waste management policy, landfill drainage monitoring is being performed at solid waste disposal sites. In long time, complicated components of the filtrate destine sedimentation of part of the elements on the drainage layer. In this kind, porosity and layer penetration decrease. The principal elements influencing the decreasing penetration – calcium, iron, manganese and carbonate compounds. Filtration at landfills established from waste humidity and atmospheric precipitation penetrating through the waste. Systematic samples were determined by seasonality. Parameters analysed showed particularly higher values when precipitation amounts are lower and vice versa. Dependency of precipitation was proved by the statistical data analysis made with Pirson's correlation coefficients.

Keywords: colmatation, drainage layer, municipal waste landfill, filtrate, municipal waste.

1. Introduction

Colmatation – washing of completely small particles into the porous sludge soil by decreasing filtration possibilities. Municipal waste landfill filtrate with soluble organic and inorganic compounds formed at waste disposal places are a consequence of chemical and biological processes in the landfills.

Modern municipal landfills in Lithuania are being exploited from 2007. Until that, municipal waste was disposed of at dumps having no filtrate or gas collection systems, often waste penetrated the surrounding territories. (Petraitis 2009). New engineering constructions completed with leachate collection systems consist of PVC perforated tubes fixed in the granulated drainage cover. In this way, precipitation from atmosphere gets into waste collection system and filtrate to the impermeable layer. Composition of such leachate depends on the type of waste in the landfill, technical parameters of the dump, age of waste, decomposition processes going and meteorological conditions. Infiltrated precipitation goes through the municipal waste and contaminates with organic and inorganic material (El-Fadel *et al.* 2002, Ettler *et al.* 2008, Zigmontiene and Zuokaite 2010). Composition of waste, technical parameters of the landfill are factors directly influenced by a man, but meteorological conditions cannot be changed. Composition of the leachate is mainly conditioned by the precipitation penetrating into the waste, however, at what level this influences the change of composition is not fully

analysed. Many organic compounds found in the leachate are variable, and identification of non-variable compounds is rare (Maximova and Koumanova 2006). Determination of qualitative parameters of the leachate is important for deciding the leachate purification method (Jaskelevičius and Lynikienė 2009). Analysis of leachate's composition allows selection of most optimal treatment equipment, search for the new ways of pollutant elimination.

The major goals of this study:

- During the seasonal filtrate quality analysis, determine their dependency on meteorological conditions (precipitation)
- Evaluate influence of precipitation on colmatation of landfill drainage layer.

2. Material and methodology

A regional landfill in Kazokiškės parish, beside Vilnius city, conforms to the EU regulations. Vilnius as one of the biggest cities in the state is a home for over 500,000 residents. Waste from the whole region of Vilnius goes to Kazokiškės landfill, making up 20,000 t/month. In the general composition of waste, around 47 % are biologically divisible (household, green waste), paper, plastic and glass make up 30 %, the remaining part consists of various other wastes (metals, flammable and non-flammable materials, hazardous waste) (Vasarevičius *et al.* 2005).

In different times of the year, different quantities of precipitation condition diverse quantities of filtrate with different concentrations (the smaller precipitation – the larger quantity of pollutants). Effect of rainwater on waste layer dissolving occurs when humidity is 45 % high, and in practice, this means that in cases up to 13,5 cm of water/m of an be absorbed before leachate starts to be produced, although this is highly dependent upon the initial moisture content of the landfill solid wastes. (Tatsi and Zouboulis 2002).

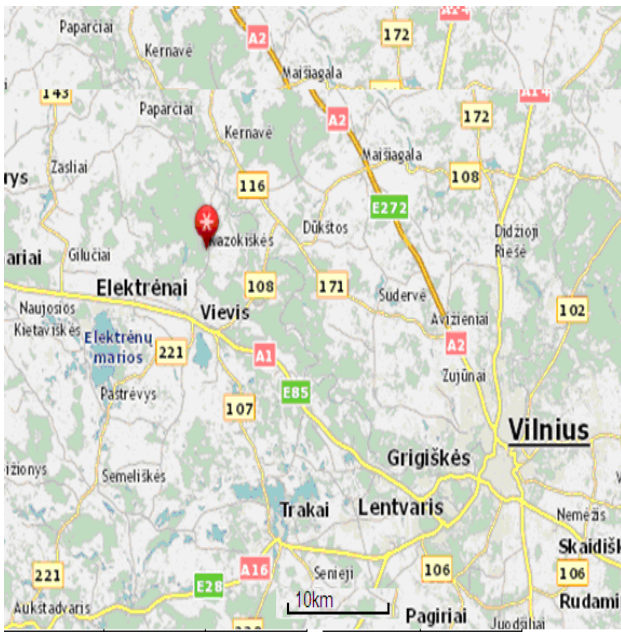


Fig 1. Geographical position of Kazokiškės landfill where samples of filtrate were taken

Filtrate samples were regularly taken from filtrate collection wells set up in the landfill (Fig 1), taken to the lab and stored in temperature not higher than 4 °C to avoid process of fermentation (Maximova and Koumanova 2006). Samples taken go through a systematic observation of changes in the following parameters: pH, ChDS, BDS, submerged particles, nitrite, nitrate, ammonium, chloride, sulphate, phosphate, carbonate and metals (Fe, Ni, Pb, Ca, Mg, Mn, Cr, Zn, Cu).

Colmatation process is directly influenced by the composition of filtrate, which itself depends on the age of landfill, equipment technology, climatic conditions, composition of waste.

3. Results and discussion

Formation of filtrate's quantity depends on waste humidity as well as atmospheric phenomena and penetrability of landfill's bottom. Several mathematic models, mainly maintained on the hydrologic balance equation, are used by many authors to calculate quantity of filtrate which mainly refer to theoretical calculations (Zhang *et al.* 2008).

A huge importance on qualitative parameters of filtrate is given on precipitation quantities, which change

during the year depending on seasonality and prevailing air masses (Marcinauskas and Korsakienė 2008). As long as Lithuania gets into the humidity excess zone, 748 mm of precipitation falls on an average through the long period, precipitation seasonality is very vivid but there is a smaller quantity of precipitation in January-April months than in May-October.

Brune *et al.* (1991) have analysed many German landfills and decided that granulated material inside the filtrate collection system can be crystallized because of microbial activities and access of solid particles into the collection layer. Authors have analysed and largely depicted qualitative parameters, however, failed to determine and rationally justify quantitative parameters in the pollution process of drainage system. Biological and chemical crystals can form inside the drainage layer and cause pollution of filtrate collection system, in this way limiting the main function of this system: a possibility to transfer liquid into collecting tubes. During analysis of different landfills, conclusions were reached that large concentration of anaerobic microorganisms in the filtrate, condition growth of mineral sedimentation and covering of drainage inside layer. The major materials influencing crystal formation were calcium and iron, combined with carbonate and sulphur (mainly in a form of sulphide). High concentration of organic and inorganic materials has a major role in colmatation process at filtrate collection systems. Pollutant material is usually made of high concentration Ca^{2+} and carbonate (CO_3^{2-}). Also noticed, that crystallized material had significant values of iron (Fe) and small quantities of magnesium (Mg) inside. This composition is a result of sand usage as a waste of covering material which is transported by leachate penetrating through waste. Sulphide alkali and pH gradient appear as a consequence of localized environment influenced by anaerobic bacteria, and are a reason for sulphide and carbonate material sedimentation.

During monitoring analysis in leachate samples (Table 1), various parameters were determined but only several conditioned colmatation. Although the phenomenon of decrease of pores penetration is not a negative factor of environment itself, however, as a consequence, leachate rich with hazardous materials can get into natural environment.

Although there is an aspiration to reduce penetration of humidity into the waste heap, but penetration of precipitation is inevitable during landfill exploitation. Chemical elements are flushed away from waste together with precipitation, but their concentrations decrease. Such a phenomenon mainly influences migrations of heavy metals. Fig 2 shows changes of precipitation quantities and carbonate quantities in a year. Increase of concentration quantities exposes in October-November-December months, but distribution is not directly influenced by the amount of precipitation. This dependency is clearly shown in the scheme below, were coefficient value is 0.2053, and it shows that dependency between CO_3 and precipitation is extremely weak.

Table1. Chemical composition of leachate from municipal solid waste landfill (* Target values for disposal treated wastewater, according to Lithuanian Government “Waste Water Regulation”)

Parameter	Units	Kazokiškių landfill		Target values*
		Average	Interval	
pH		6,96	6,5-7,39	
ChDS	mgO/l	2160	850-2278	125
BDS	mgO/l	1460	570-3800	17
SD*	mg/l	88	29-124	
Cl ⁻	mg/l	676	148-2344	1000
SO ₄ ²⁻	mg/l	405	169-955	300
HCO ₃ ⁻	mg/l	3953	1200-7330	
NO ₂ ⁻	mg/l	1,123	0,05-8,524	1,5
NO ₃ ⁻	mg/l	1,43	0,05-7,2	100
NH ₄ ⁺	mg/l	1320	668-3098	
Na ⁺	mg/l	750	105-1815	
K ⁺	mg/l	444	120-718	
Ca ²⁺	mg/l	492	209-2284	
Mg ²⁺	mg/l	211	141-255	
Fe	mg/l	5,99	1,73-10,4	
Pb	mg/l	0,04	0,01-0,176	0,1
Zn	mg/l	0,15	0,08-0,22	0,4
Cr	mg/l	0,15	0,05-0,22	0,5
Ni	mg/l	0,26	0,12-0,45	0,2
Cu	mg/l	0,029	0,015-0,037	0,5
Mn	mg/l	0,267	0,185-0,409	

Quantity of calcium and change of its concentration has influence on colmatation processes in the drainage layer. Largest quantities of this element form in October-November-December, the same as that of carbonates. Although the precipitation quantity peak is in June-July months, but Ca concentration decreases at the beginning of the year and at summer season end.

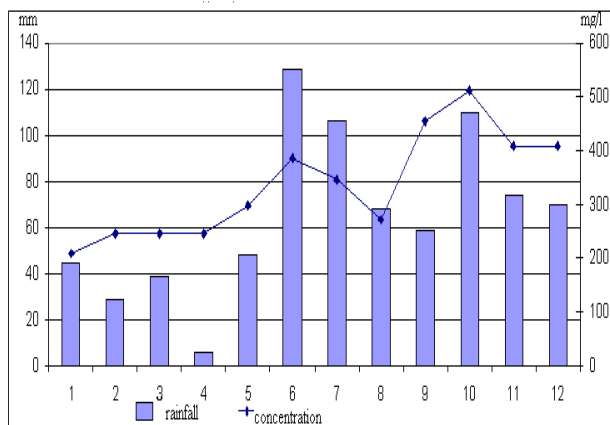


Fig 4. Change of Ca and precipitation quantities in 2009 (1 - January, 2 - February....11 - November, 12 - December)

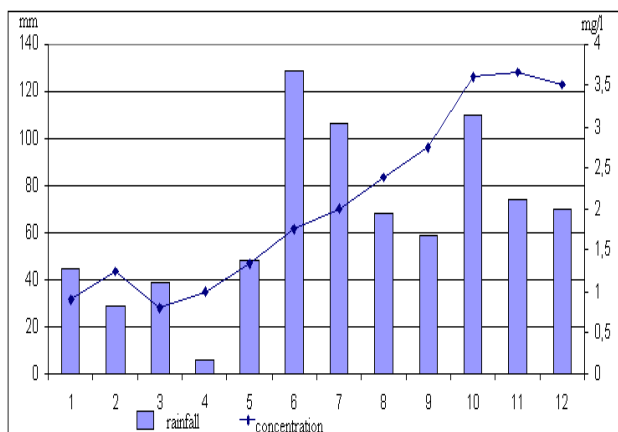


Fig 2. Change of CO₃ and precipitation quantities in 2009 (1 - January, 2 - February... 11 - November, 12 - December)

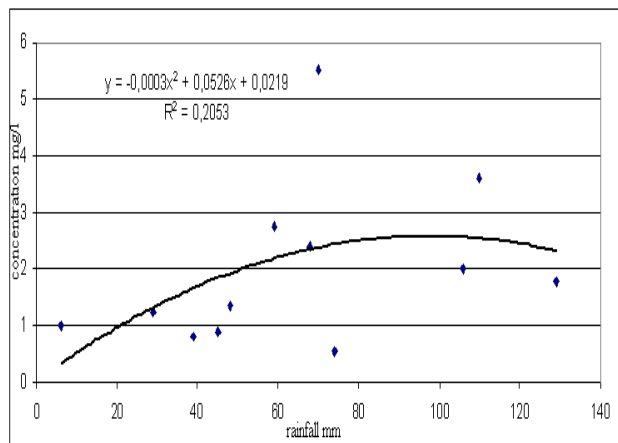


Fig 3. Dependency of CO₃ and quantity of precipitation

Direct dependency of precipitation quantities and change of concentrations is shown on the curve in Fig 5. Coefficient value 0.46 shows that dependency is average and precipitation has influence on Ca quantities, even if minute. Changes of calcium quantity in filtrate are destined by the composition of waste and usage of material for waste covering (El-fadel *et al.* 2002). The element itself has no danger to environment but their conglomeration makes barriers to various processes (filtration through drainage layer).

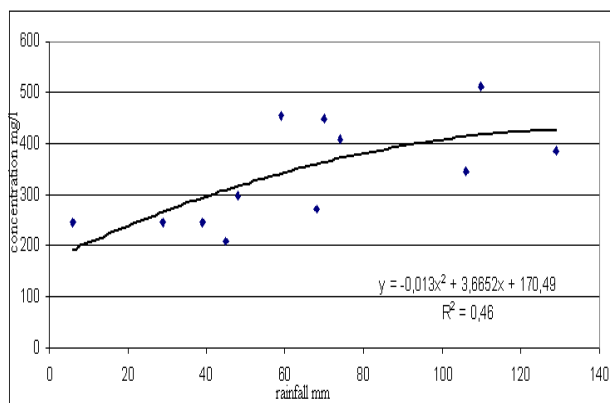


Fig 5. Dependency of Ca and precipitation quantity changes

Colmatation is influenced also by magnesium and iron compounds. Their distribution is shown in Fig 6–7. The greatest influence of those two elements on colmatation is noticed during analysis of materials crystallized between drainage (McIsaac 2008). During sedimentation on drainage particles, pores shrink and decrease layer penetration.

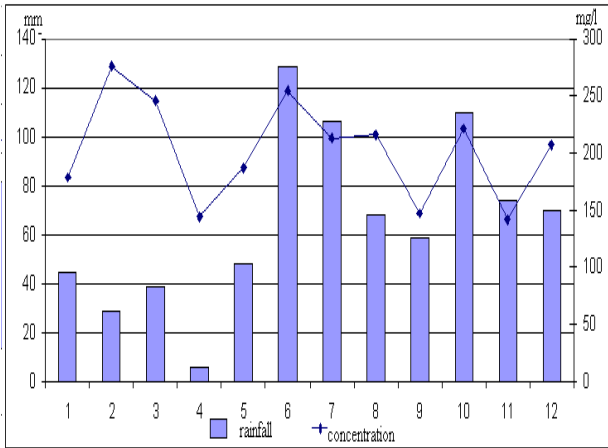


Fig 6. Change of Mg and precipitation quantities in 2009 (1 - January, 2 - February....11 - November, 12 - December)

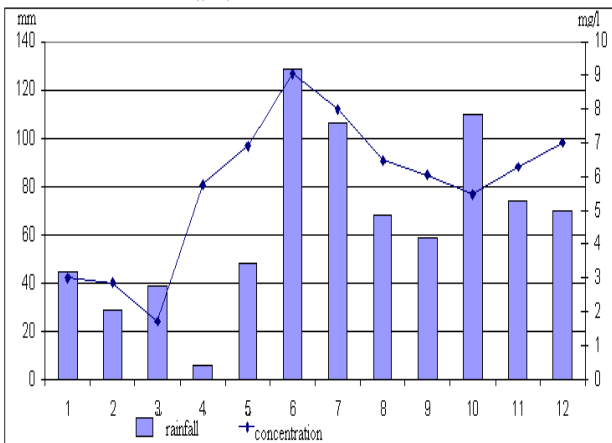


Fig 7. Changes of Fe and precipitation quantities in 2009 (1 - January, 2 - February....11 - November, 12 - December)

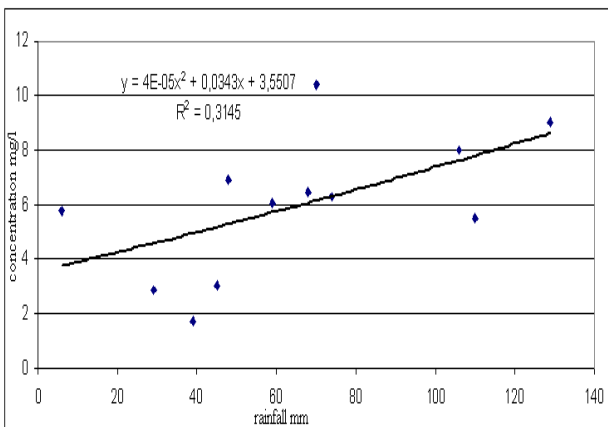


Fig 8. Dependency of Fe and precipitation quantity changes

Atmospheric precipitation has no influence on the changes of magnesium concentration – Fig 6 shows how concentration curve alternates irrespective of precipitation quantities. The calculated correlation coefficient is zero, therefore, it is suggested that changes in magnesium concentrations depend on waste composition changes and

not on atmospheric conditions. There is also a proposition that decrease of drainage layer penetrability conditioned by growing magnesium sedimentation, has no relation to the changes of meteorological conditions.

Although Fe_{2+} concentrations are considerably lower than that of Mg_{2+} , but they show a weak link and with precipitation (Fig 7) Correlation coefficient 0,31 shows average relation intensity (Fig 8).

Although quantity of precipitation mainly impacts migrations of heavy metals and concentration changes, but uneven quantities of precipitation falling down in different seasons of the year, destine the quantity of filtrate's component parts forming in the landfill.

4. Conclusions

1. Research was made and systematic calculations used to measure the major parameters in filtrate samples. The existing data show that changes in filtrate component concentrations can have influence on colmatation processes. Statistical correlation calculations were made and influence of atmospheric precipitation was observed. The later calculations allow deciding about the larger influence of meteorological conditions when the waste pile is not covered and directly impacted by environment.
2. There are many literature resources analysing colmatation in landfills. Most of the literature gives information on correlation analysis of filtrate's parameters, influence of drainage layer particles size on decrease in penetration, but meteorological conditions are often left aside or even not analysed. In the analysis, we have compared not only quantities of filtrate's parameters showing that difference in composition can be conditioned by many factors: composition of waste, age of waste, engineering solutions, but also a possible influence of meteorological conditions on changes in filtrate's parameters is analysed.
3. After performance of analysis, only a slight influence of meteorological conditions is observed (correlation coefficients fluctuate from 0.2 to 0.4), but the impact exists and shows that attention must be paid to atmospheric precipitation also during filtrate composition analysis. Many of the measured amounts have a very weak correlation relation showing a weak dependency on weather conditions and precipitation. The received results allow thinking of possible changes in filtrate parameter concentration values. This information can help to adapt new methods and innovative technologies allowing maximum decrease of influence of atmospheric phenomena to waste in landfills.

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