University of Tehran Press

Pollution

Print ISSN: 2383-451X
Online ISSN: 2383-4501

https://jpoll.ut.ac.ir/

Simulating of Clogging Process in the Leachate Collection System in the Municipal Solid Waste Landfill using Column Experiments

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Article Info

Article type:
Research Article

Article history:
Received: 2 Feb 2023
Revised: 24 April 2023
Accepted: 27 May 2023

Keywords:
Drainage layer clogging
High strength leachate
Landfill simulation
Permeability

ABSTRACT

Clogging of the drainage layer is the main reason for the inefficiency and failure of the leachate collection system in municipal solid waste (MSW) landfills. One of the most important challenges in the design and operation of landfills is to identify the factors affecting the drainage layer clogging and the extent of their influence especially in the real scale. In this study, five experimental columns were designed to investigate the effective factors on the clogging of the drainage system in the MSW landfills, making it possible to measure the effect of different parameters on the drainage layer clogging through simulating the real conditions. The designed columns are capable to apply the boundary conditions of the MSW landfill including temperature, pressure, and leachate recirculation as well as measuring the permeability of drainage layer. High strength real leachate recirculated in the experimental columns to monitor the degree of drainage layer clogging through the regular measurement of permeability in the different columns. The results showed hydraulic conductivity of the drainage layer decreased between 20 to 50 percent in different samples over time. Although the particle size of drainage materials directly influences the reduction of hydraulic conductivity, the common concentration of calcium carbonate in the materials of the drainage layer does not considerably affect this issue. Formation of biofilm in the drainage layer was observed through scanning electron microscope (SEM) and visual inspection in all columns indicating the proper performance of clogging process simulator which is designed and developed in this research.

Cite this article: Golhosseini, Z., Jalili Ghazizade, M., and Safari, E. (2023). Simulating of Clogging Process in the Leachate Collection System in the Municipal Solid Waste Landfill using Column Experiments. *Pollution*, 9 (3), 1281-1294.
https://doi.org/10.22059/poll.2023.355280.1785

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DOI: https://doi.org/10.22059/poll.2023.355280.1785

INTRODUCTION

Nowadays, despite the significant increase in the reduction, reuse and recycling of municipal solid waste (MSW), sanitary landfilling of waste is still the most widely used method in MSW management in the world due to its short term economic benefits, especially among the developing countries (Kaza et al., 2018). Landfills have different kinds of environmental impacts which depend on the various factors such as landfill location and type, quantity and composition of the incoming waste, and climate situation (Frikha et al., 2017). Nevertheless, previous studies have shown that the maximum pollution potential in the executive management of landfills is related to the generation and leakage of leachate (Wijekoon et al., 2022; Sivakumar, 2013). The proper design and implementation of the leachate collection system, which drain the leachate and discharge it to a specific place outside the landfill, is one of the most important requirements of the MSW landfill which prevents the accumulation of leachate on the liner as well as leachate penetration into the subsoil and groundwater resources (Cossu and Rainer Stegmann, 2019).

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There are various methods and equipment for leachate collection which are used depending on the different landfill conditions. Normally, the drainage and leachate collection system includes a drainage layer with high permeable granular materials (more than 1×10^{-3} m/s) accompanied with leachate collection and transfer pipes made of high-density polyethylene (HDPE) (Yu and Rowe, 2012). The high permeability of the drainage layer facilitates the transfer of leachate from the landfill surface to the leachate collection pipes and provides the possibility of controlling the leachate head on the liner (Rowe and Yu, 2013a). Drainage layer clogging is considered as one of the most important concerns in designing and implementing landfills since it reduces the void space in this layer leading to decrease permeability over time and disrupt the leachate flow toward the sump (Townsend et al., 2015).

A large number of studies have been conducted about the effective factors on the clogging of the drainage layer, the results of which indicated that factors such as the particle size of the drainage materials, leachate composition and flux, temperature, using a separating layer between the MSW and the drainage layer, saturated conditions versus unsaturated conditions are among the most effective factors on the leachate collection system clogging (Bian and Liu, 2014; Rowe and Yu, 2010; Paksy et al., 1998; Rowe et al., 2000a; McIsaac and Rowe, 2007; Fleming and Rowe, 2004; Armstrong, 1998). Since clogging of the porous media generally leads to some changes in the hydraulic characteristics of this medium, so permeability can be used as an indicator to evaluate the expansion of the clogging. In many natural and artificial systems, microbial growth and biomass accumulation may lead to the closing of the porous medium and significant changes in the transport properties of the said medium. Biological clogging reduces the porosity, transmissivity and hydraulic conductivity of porous media through changing the geometry and size of the pores, the friction coefficient and the fluid viscosity (Rowe et al., 2002). Moreover, non-biological mechanisms including physical processes (such as particle deposition), chemical ones or a combination of them lead to a decrease in the hydraulic conductivity of the porous medium (Thullner et al., 2002). Numerous studies have yet investigated the reduction of hydraulic conductivity caused by microbial growth using column experiments. The results indicated a significant reduction of hydraulic conductivity due to biological clogging (Taylor et al., 1990; Cunningham et al., 1991; Vandevivere and Baveye, 1992; Rinck-Pfeiffer et al., 2000). Furthermore, some focused on showing the drainage layer clogging in the MSW landfill, monitor the changes in permeability of the porous medium as a criteria for the expansion of clogging (Rowe et al., 2000a; Baziene et al., 2012; Vieira et al., 2010). A review on research background indicated that inefficiency of the leachate collection system leads to an increase in the leachate head on the liner, while increasing the possibility of leachate leakage to the surrounding environment. So avoiding the accumulation of leachate on the liner increases the efficiency of the liner through reducing the leachate head. Moreover, it decreases the retention time of leachate in the MSW pile, and as a result the transfer of pollutants from the solid phase to the liquid phase, as well as ensuring the stability of the waste mass and maintaining the physical integrity of the landfill (Booker et al., 2004). Therefore, identifying the effective factors on the clogging of the leachate collection system by considering the conditions of the MSW landfill and the characteristics of the generated leachate play a significant role in the proper design of this system and its optimal performance. Meanwhile, due to the generation of high strength leachate in Iran's landfills, which is mainly caused by the significant share of putrescible waste in the MSW composition in Iran, the importance of clogging in the drainage layer is highlighted more than ever. In addition, the different pattern of leachate generation in landfills located in arid and semi-arid areas of Iran, which is more affected by the MSW moisture not rainfall, makes uncertain the direct use of research results and international standards. Hence, it is essential to simulate the clogging process in Iran's landfills according to the actual characteristics since it provides the necessary platform for developing the required national standards in this regard. Therefore, the present study designs and develops a laboratory pilot, as well as proposes a method to monitor and measure the amount of clogging in the leachate collection system in order to compare the effect of different parameters on the clogging of the leachate drainage system.

MATERIALS AND METHODS

Pilot Design and Development

It is necessary to have a comprehensive understanding of the conditions of leachate generation and drainage in the landfills in order to design and build a setup for MSW landfill simulation. Leachate flow through drainage layer is affected by different criteria which should be considered in landfill simulation. Based on the results of various studies, placement of the different layers in laboratory cell, mechanism of leachate recirculation, leachate head adjustment, simulation of temperature and pressure exposed to the laboratory cell, and the possibility of measuring different variables are the most important factors which should be considered in the design and development of an experimental setup (Baziene et al., 2012; Fleming and Rowe, 2004). Accordingly, steel cylindrical columns with a length of one meter and an internal diameter of 10 centimeters were designed and constructed to apply the real conditions of the MSW landfill in the laboratory. Figure 1a displays the schematic of each column consisting of an inlet valve at the top and three valves at a distance of 15 centimeters from each other. The two upper valves which are shown with number 5 in Figure 1a are installed above the liner to adjust the leachate head, which makes possible measuring hydraulic conductivity of drainage layer via connecting to the manometer. Valve number 6 is used to drain the leachate from the bottom of the drainage layer as well as to connect the manometer. Furthermore, a separate valve is installed at the bottom of the column to facilitate monitoring of leachate leakage through the body or across the liner. A longitudinal cut, which is opened and closed through bolt and nut, was put in the middle of each column for sampling and photographing the contents of the column (soil and clogged materials) at the end of the experiment.

Applying the pressure induced by the waste on the lower layers is an important item in the process of designing the MSW landfill pilot. It is usually in the range of 100 to 250 kilopascal depending on height and density of the compacted MSW and the landfilling method (Bagchi, 2004). The use of an air bladder is considered as one of the methods for applying pressure in laboratory columns (Rowe et al., 2015), which is associated with problems such as perforation due to contact with sand particles. To overcome this problem, an innovative system consisting of a plate and four bolts has been used to apply pressure to the soil in the designed column. Thus, a metal plate is placed on the drainage layer and the required pressure is applied to this plate through four bolts, and the pressure is adjusted by measuring the torque with a torque meter.

Temperature is another item which should be considered in the simulation of the MSW landfill, especially in the studies focused on the process of drainage layer clogging. The composition of incoming MSW, existence or non-existence of a leachate collection system, and landfill age are among the factors which affect the temperature into the landfill (Safari et al., 2012). Based on the studies conducted on the temperature of the MSW landfill, the temperature at the bottom of the landfill is around 30-40 degrees Celsius (Hoor et al., 2008). This temperature range is also true for Iran's landfills where Shariatmadari et al. (2011) reported that the temperature in drainage layer varies between 35°C to 46°C in Tehran's landfill. However, the anaerobic decomposition of organic materials in the MSW, the absence of a leachate collection system, or leachate recirculation can increase the temperature of the landfill up to 60 degrees Celsius (Rowe and Hoor, 2009). One of the methods to adjust the temperature inside the laboratory column is heating the leachate before entering the column, which was used in the previous studies (Safari et al., 2012). Since the change in the temperature of the leachate may disrupt the natural clogging mechanism in the drainage layer, a thermal cover, consisting of two elements, a thermostat, aluminum foil and glass wool, was used in the present study to regulate the temperature of the columns. Each element is plugged into a separate electrical outlet which is equipped with three-phase power. Electrical energy is converted to heat caused to increase temperature in drainage layer. Each element is equipped with a thermostat to control the temperature and aluminum foil and glass wool help avoid heat loss. All columns are equipped with this system with a separate electrical circuit in order to provide the required temperature for each column separately.

Two 100-liter tanks were used, one on the ground and the other one at a height of 2.5 meters from the ground, for injecting leachate into each column and recirculating it. After evacuating the natural leachate in the lower tank, the leachate enters the upper tank through an afloat pump and then enters the columns through a main pipe and a flow-control valve. After passing through the drainage layer in each column, the leachate enters a main pipe through the head adjustment valve (number 5 in Figure 1a) and then discharge to the lower tank. Therefore, the process of recirculating the fresh leachate in the system is performed.

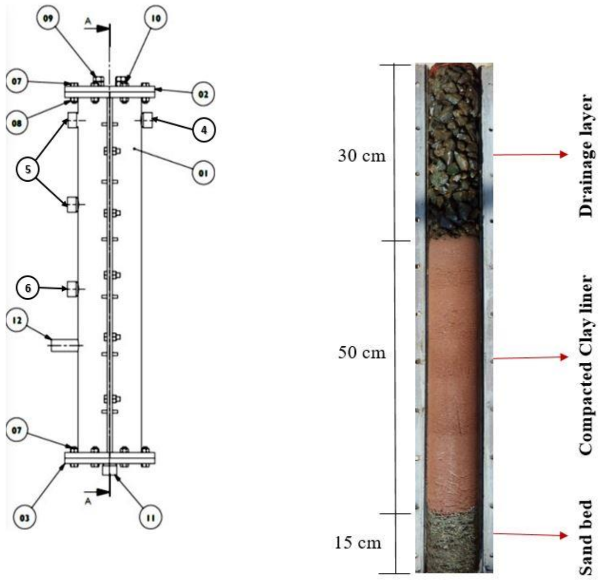
In order to simulate the layers of the MSW landfill, a sand layer with a thickness of 15 centimeters is placed at the bottom of each column as a bed for the liner compaction. Then, using appropriate clay, the compacted clay liner with a thickness of 50 centimeters (five layers of 10 centimeters) is made in each column. Finally, a drainage layer with 30 centimeters thickness is placed above the liner using granular materials (Figure 1b). Based on existing standards, the thickness of the drainage layer in the MSW landfill should be at least 30 centimeters (EPA, 1993)

Finally, while putting a rubber ring among the two component of the column, a cap is placed on the column so that anaerobic conditions are provided inside the column after the leachate enters the porous medium of the drainage layer. Two manometers are used to monitor the changes in the hydraulic conductivity of the drainage layer. A tapeline is installed on the wall next to the manometers of each column to determine the height of the leachate.

Pilot Installation and Commissioning

Column experiments were conducted to measure the degree of clogging in the landfill drainage layer. In this regard, experimental columns were designed and built to monitor the degree of clogging of the drainage layer as well to simulating the MSW landfill. In addition, the designed columns were capable to adjust the desired temperature and pressure. In this research it has been tried to make the operational conditions of the columns similar to the actual conditions of the MSW landfill. Therefore, considering the density of landfilled MSW equal to 800 kg/m^3 and the waste height equal to 30 meters (Safari et al., 2012), a pressure equivalent to 240 kilopascals applied to the drainage layer using a torque meter. In addition, the temperature of the columns was set at 40±2 degrees Celsius using a thermostat. In order to measure the hydraulic conductivity of the drainage layer, two manometers were installed on each column in the place of the 30 cm head valve and the outlet valve (the distance between the manometers is equal to 30 cm). The leachate is pumped from the lower tank to the upper tank and enters the columns with a flow rate of 100 liters per day. Normally, the leachate head on the liner was considered equal to 30 centimeters in order to simulate the worst conditions of the drainage layer. Therefore, the leachate was removed from the upper valve (30 cm head adjustment valve) of each column and recycled to the lower tank through a pipe. For permeability measurement, the head adjustment valve is closed and the leachate is discharged from the outlet valve located at the bottom of the drainage layer and above the liner surface (No. 06 in Figure 1). After reading the leachate head in the manometers, the head difference between the top and bottom of the drainage layer was recorded to calculate the permeability of drainage layer. Five columns with the mentioned characteristics were designed and constructed to determine the degree of drainage layer clogging in different conditions. Figure 2 shows the general structure of this system.

01	Column steel body
02	Top cap
03	Bottom cap
04	Leachate inlet valve
05	15 and 30 cm head adjustment valves
06	Leachate outlet valve
07	Bolt of closing the cap
08	Nut
09	Pressure adjustment bolt
10	Nut
11	Leakage monitoring valve
12	Location of the monitoring sensors (if necessary)



(a) (b)

Fig. 1. (a) The components of the designed column; (b) The longitudinal section of the column (simulation of MSW landfill cell)

Fig. 2. The setup of designed columns to determine the effective factors of the drainage layer

Monitoring method of clogging

Hydraulic conductivity changes can be considered as one of the most important indicator to determine clogging in the leachate collection system. Since drainage layer clogging are affected by different parameters, so several columns were used to make it possible to investigate the effective parameters on the clogging of the drainage layer in the MSW landfill. According to previous studies, the size and amount of lime in the particles of the drainage layer is considered as one of the most important factors in the clogging of the leachate collection system (VanGulck et al., 2003; Rowe and Yu, 2013b). Five columns, structurally similar to the ones described in the previous section, were used to evaluate the effect of particle size and calcium carbonate concentration of drainage materials on the degree of clogging. In this regard, the size distribution of drainage materials in three columns, and concentration of calcium carbonate in the other two columns are considered as variables. In columns with different size distribution (5-8, 8-19, and 19-50 millimeters), the concentration of calcium carbonate is constant and equal to 7%, in columns with variable calcium carbonate concentration (7%, 14%, and 55%), the size distribution is considered constant and equal to 19-50 millimeters for drainage materials. Attempts were made to keep the other prevailing conditions the same during the system operation. Based on existing standards, the permeability of the granular materials used as the drainage layer should be more than 10^{-2} cm/s (EPA, 1993). The primary hydraulic conductivity of drainage materials was measured using the constant head method according to ASTM D 2434 standard (ASTM, 2010). The particle size, calcium carbonate concentration and hydraulic conductivity of drainage materials in each column is presented in Table 1. Accordingly, the permeability of all types of drainage materials is greater than 10^{-1} cm/s.

Gravel samples with different particle size and calcium carbonate concentrations were prepared and placed inside the columns based on the results shown in Table 1. Fresh leachate provided from Tehran's landfill (called Aradkouh) was used to recirculate through the columns. The leachate characteristics is shown in Table 2. The most popular indicators for organic load of leachate are COD, BOD and TOC. However the amount of organic pollutants are not significant in comparison with the other sampled leachate from Tehran's landfill (Safari et al., 2012), but the strength of this leachate can be categorized as intermediate based on landfill leachate classification by Renou et al. (2008).

The leachate was poured into the lower tank, then pumped into the upper tank and entered into the columns from there. Since incoming leachate loses its initial properties after a certain period of time, the entire leachate was replaced with new fresh leachate each month. Column inlet valves adjust the leachate injection flow rate to each column. As mentioned, the changes in the hydraulic conductivity of the drainage layer indicate the level of clogging. Therefore, the hydraulic conductivity of this layer was measured every two weeks for nine months using the constant head method. While measuring hydraulic conductivity, the inlet valves of other columns are closed and only the column whose hydraulic conductivity is measured has an input. The height of leachate in the upper tank is kept constant and the flow rate is measured after the flow is fixed. The measurements were carried out in a constant hydraulic gradient in

Table 1. Characteristics of the drainage materials of the designed columns

Column number	Drainage layer particle size (mm)	Calcium carbonate concentration (%)	Hydraulic conductivity (cm/s)
1	5-8	7	0.228
2	8-19	7	0.306
3	19-50	7	0.338
4	19-50	14	0.341
5	19-50	55	0.357

Table 2. Characteristics of the leachate used in experimental columns (provided from the Aradkouh MSW landfill)

parameter	unit	concentration	parameter	unit	concentration
Ba^{2+}	mg/l	0.84	Total P	mg/l	4.04
Co^{2+}	mg/l	2.31	TSS	mg/l	708
Cr^{6+}	mg/l	1.74	VSS	mg/l	94
Cu^{2+}	mg/l	2.60	DOC	mg/l	443
Al^{3+}	mg/l	6.93	TOC	mg/l	1042
Mn^{2+}	mg/l	0.64	pH	pH Value	8.23
Fe^{3+}	mg/l	9.35	TDS	mg/l	21350
Ni^{2+}	mg/l	1.33	EC	Ms/cm	33.84
Zn^{2+}	mg/l	0.78	TKN	mg/l	4555
Na^{+}	mg/l	1422	Alkalinity	mg/l	9000
K^{+}	mg/l	956.80	CO_3^{2-}	mg/l	0.0
Mg^{2+}	mg/l	179.8	HCO_3^{-}	mg/l	9000
Ca^{2+}	mg/l	352.7	BOD5	mg/l	5890
Cl^{-}	mg/l	7810	COD	mg/l	8244
SO_4^{2-}	mg/l	600			

TSS: Total Suspended Solids; VSS: Volatile Suspended Solids; DOC: Dissolved Organic Carbon; TOC: Total Organic Carbon; TDS: Total Dissolved Solids; TKN: Total Kjeldahl Nitrogen; EC: Electrical Conductivity; BOD: Biological Oxygen Demand; COD: Chemical Oxygen Demand.

order to record the hydraulic conductivity changes over time, as well as comparing the columns with each other. The hydraulic conductivity of the columns was calculated using the following equation and the results were compared over time.

$$Q = A.K_S.\frac{\Delta H}{L}$$

Where, Q is Flow rate (cm^3), A is Cross section (cm^2), K is Hydraulic conductivity (cm/s), H is Hydraulic head (cm) and L is Distances among manometers (cm).

Finally the columns were opened and clogged materials were sampled from different parts of drainage layer to be more assessed. Sampling the drainage layer and the clogging materials in the longitudinal profile of each column was conducted for determining the characteristics of the materials resulting from the clogging of different columns. The presence of microorganisms in drainage layer was assessed by visual observation as well as using a scanning electron microscope (SEM). The clog materials were mounted on the copper tab and then it was put on a stab and was coated with a layer of gold, about 10 nm by a desktop Magnetron sputtering. The Hitachi SU3500 (Hitachi, Japan) with the accelerating voltage of 25Kv was used for this analysis (Heidari and Jalili Ghazizade, 2021). The samples were also transferred to the laboratory and their characteristics were determined after separating the clogging materials from drainage layer. Samples were taken from different heights of drainage layer (0, 15 and 30 centimeters) in order to evaluate the changes of clogging in each column. The height of 0 centimeter means the top of the column at the leachate entering, and the height of 30 centimeters is the bottom of the drainage layer at the junction of the drainage layer with the liner. Total dry solid and total volatile solid were measured using the EPA 1684 standard method (EPA, 2001).

RESULTS AND DISCUSSION

The permeability of the drainage layer as an indicator of clogging was measured in different columns at monthly intervals (Figure 3). As shown in Figure 3, the permeability of the drainage layer in all columns has a decreasing trend compared to the initial conditions. The most important reason for this problem is the clogging of the drainage layer exposed to the leachate over the time. The decreasing rate of permeability (i.e. the ratio of permeability reduction during the experiment to initial permeability) in the first column was about 50 percent. The highest amount of decrease in permeability is related to the first column, where the smaller particle size of the drainage layer material allows the growth of microorganisms and the deposition of leachate suspended particles. This result confirms findings of Rowe et al. (2000b) where they reported 55 percent decrease in drainable porosity of the smallest particle size of drainage material. The pattern of drainage layer permeability changes in the second column is similar to the first column. The permeability of drainage layer in the second column was constant during the first months which reveals that the biological clogging mechanism is prevailing phenomena in this column. The decreasing rate of permeability in the second column was about 32 percent. Smaller particle size of drainage layer in this column caused to higher permeability reduction in comparison with the other three columns. In columns 3-5, where coarse-grained materials were used as the drainage layer, the amount of permeability reached a constant level after an initial reduction in the hydraulic conductivity, which is principally caused by the deposition of suspended particles. The decreasing rate of permeability in columns 3 to 5 is 20.6, 20.8 and 29.9 percent respectively. In the same grading particle size of drainage layer material providing by VanGulck and Rowe (2004), 10-38 percent decreasing in drainable porosity was reported. The results indicated that changes in the percentage of lime do not have a significant effect on the performance of the drainage layer. Although long-term analysis is required for the result in this regard, the overall results indicate the optimal performance of the designed columns in the simulation of clogging process in the landfill drainage layer.

Opening the columns after the end of the experiment period provides information about the characteristics of the biofilm formed in the material of drainage layer, density of the clogging material, microbial population, and elemental analyses of the clogging material, and etc. Based on the predictions made at the time of design, the columns were opened from both sides without disturbing the simulated layers in order to observe the clogging created in the drainage layer

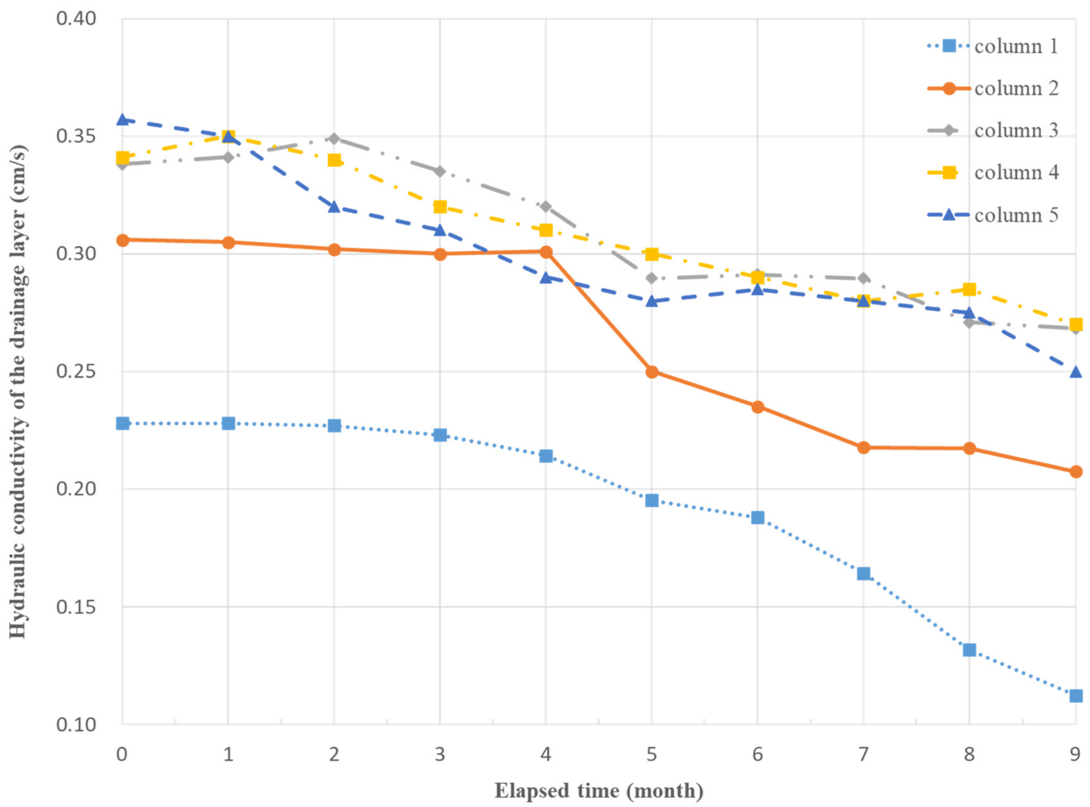
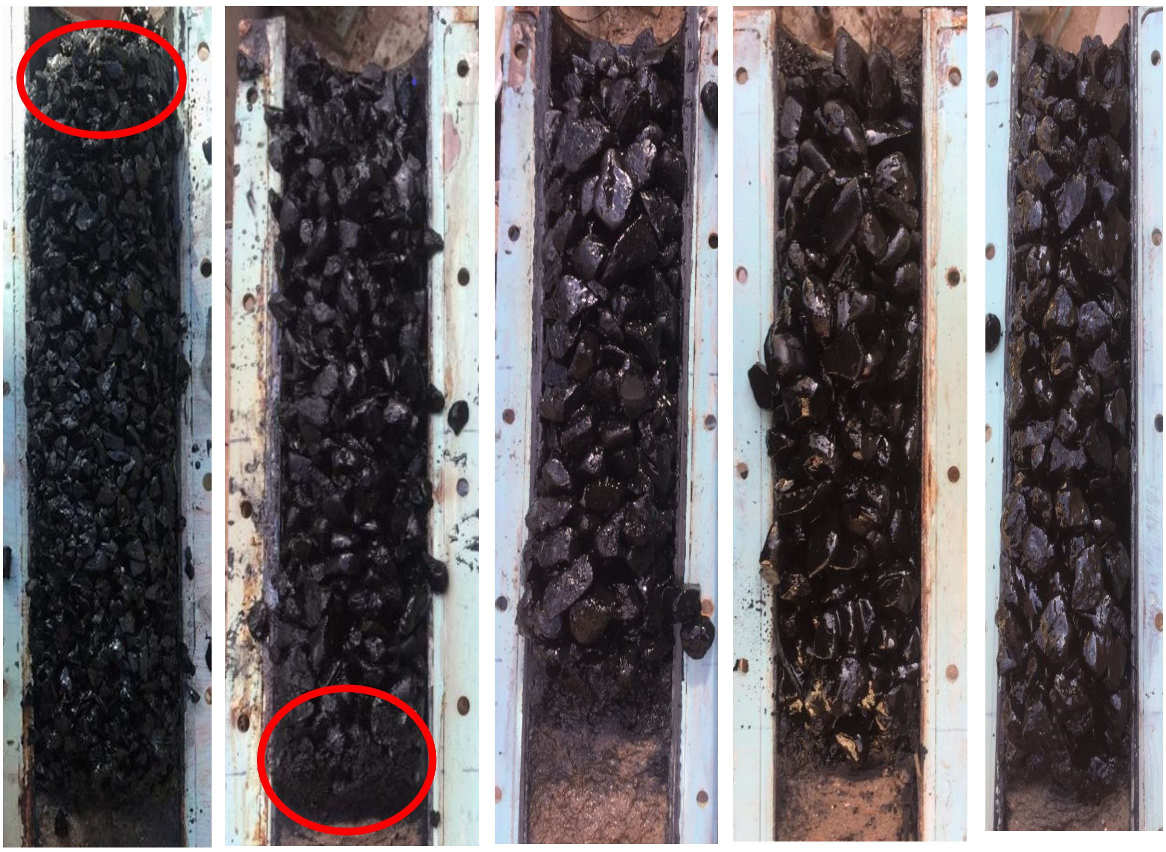


Fig. 3. Changes of the permeability of the drainage layer in laboratory columns over time

about one year after beginning of the test. Figure 4 shows the drainage layer materials in the different opened columns. As shown, the appearance of the drainage materials completely changed and turned black due to long-term exposure to the high strength leachate. Passage of high organic material contained leachate through the drainage layer lead to the growth of biofilms, the deposition of mineral particles and the accumulation of suspended particles which in turn leads to porosity reduction. The amount of clogging in the longitudinal profile of each column varies depending on the size distribution of the drainage materials. In the columns with coarser particles, the maximum amount of clogging occurred at the bottom of the drainage layer and in the vicinity of the liner surface (column 2 in Figure 4). However, in column 1, which has a finer size distribution of drainage layer (the particle size is between 5 and 8 millimeters), the maximum amount of clogging occurred at the top of the column and leachate inlet, which shows the importance of using coarse-grained materials in the drainage layer. It was previously found by Rowe et al. (2000a) that clogged materials accumulate in the head and bottom of column with small particle size of drainage material. Uniform distribution of clogged material in the column with larger particle size was also reported by Rowe et al. (2000a). If the retention time of the high strength leachate increases in the initial parts of the drainage layer (due to the fine particle size of the materials), especially by clogging the upper part, the performance of the entire drainage layer is disturbed and the leachate enters the waste layers. Consequently, it seems necessary to use materials with average particle size larger than eight millimeters to be applied as drainage layer materials.

However, the material resulting from the clogging has become so hard in some cases, which cannot be removed by hand and separated from this layer by difficulty, Figure 5a and 5b

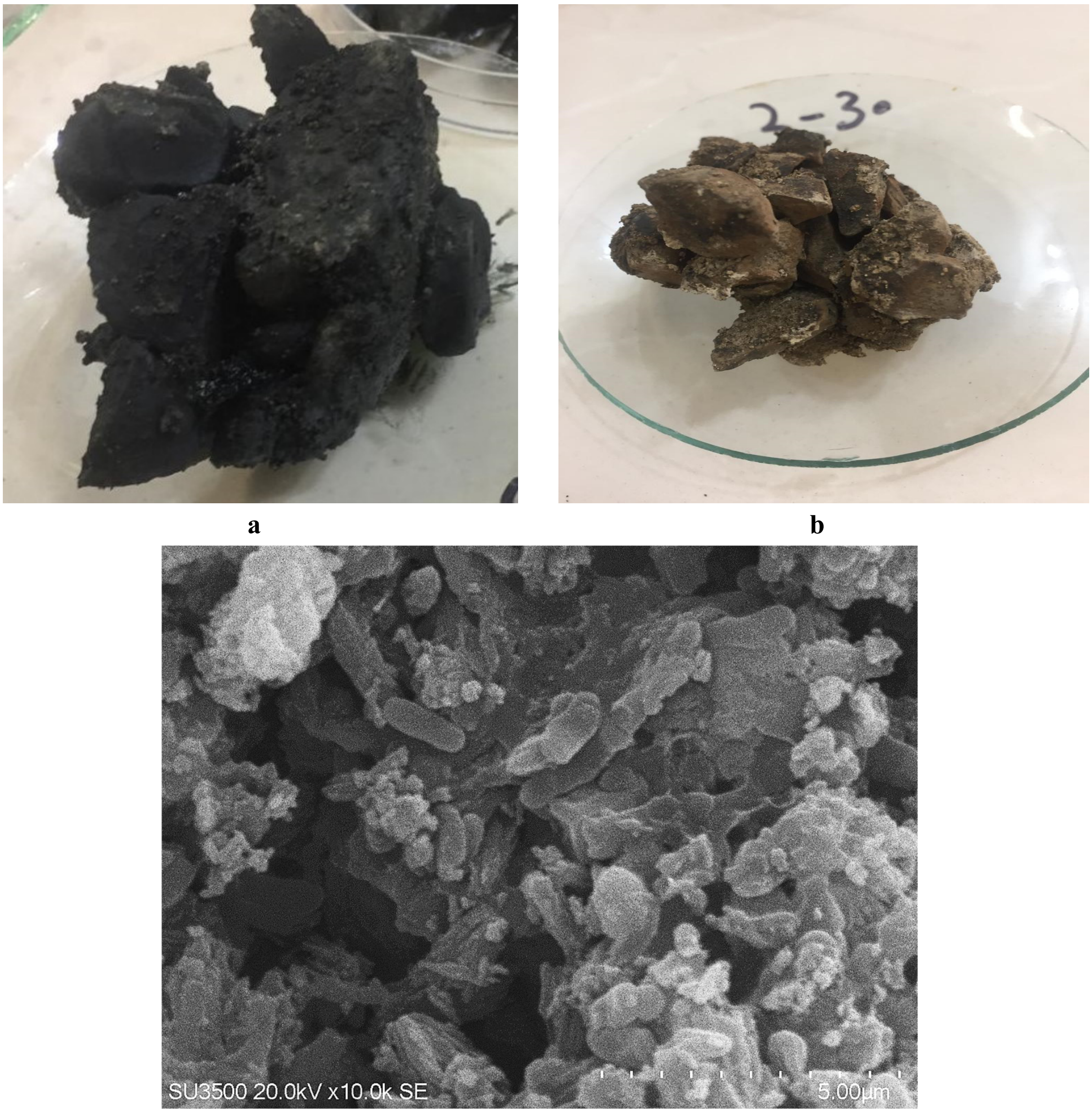


Column 1 Column 2 Column 3 Column 4 Column 5

Fig. 4. Clogging of the drainage layer caused by the leachate passage during one year

show the raw sample and dried sample taken from the second column respectively. Growing microorganisms in different samples can be also seen clearly in the photos taken by scanning electron microscope (SEM). Figure 5c illustrate the presence of microorganisms in clogged material sampled from one of the columns. This kind of clogging was reported previously by (VanGulck and Rowe, 2004; Levine et al., 2005; Ramke, 1986). Visual observations at the end of the experiment indicated the formation of biofilm in the drainage layer, which confirmed the proper performance of the designed columns in simulating the process of clogging in the drainage layer.

Table 3 shows the results of drainage material analyses. The total dry solids and moisture in the samples ranges 90-97%, and 3.5-9.6% respectively. In addition, the low percentage of volatile solids in the samples, which varies between 0.8 and 2.6%, indicates that most of the clogging material is caused by the deposition of suspended particles in the leachate. Therefore,



c

Fig. 5. A sample of clogging materials of the drainage layer in the second column: a) Raw sample; b) Dried sample; c) SEM micrograph of clogged material (scale bar 5 µm)

Table 3. The results of drainage materials characterization in the longitudinal profile of laboratory columns

Column number	Sample taken location (centimeters)	Total dry solid percentage	Moisture percentage	Volatile solid percentage
1	0	90.6	9.4	2.1
	15	93.4	6.6	2.0
	30	90.4	9.6	2.6
2	0	93.8	6.2	1.7
	15	95.1	4.9	1.4
	30	93.1	6.9	1.7
3	0	96.1	3.9	1.1
	15	96.1	3.9	1.1
	30	94.0	6.0	1.3
4	0	96.7	3.3	1.1
	15	96.6	3.4	0.9
	30	95.2	4.8	1.0
5	0	94.2	5.8	0.9
	15	94.3	5.7	0.8
	30	95.0	5.0	1.1

using a filter on the drainage layer can be considerably effective to prevent the clogging.

The results obtained from the changes in permeability of the drainage layer, as well as visual observations and laboratory analyses of clogging materials in the columns, indicated that the simulation of the clogging process in the drainage layer was done well by column experiments. The clogging in the drainage layer can be properly quantitated by changing the characteristics of the layer drainage and conducting long-term experiments.

CONCLUSION

Generally, the leachate collection system plays a significant role in the appropriate performance of the landfill by controlling the leachate head on the bottom liners and preventing pollution emission to the surrounding environment. Drainage layer clogging is one of the challenges arisen in municipal waste landfills which in turn leads to a decline in the efficiency of the leachate collection system. Several mechanisms of clogging have been identified, including physical clogging due to leachate particle transport, chemical clogging resulting from mineral deposits, and biological clogging due to microbial growth, which mainly work in opposition to each other. Due to the relationship between microbial activities and chemical reactions, the biological and chemical mechanisms are usually examined in combination with each other under the title of biochemical clogging.

Various items such as particle size of the drainage layer materials, leachate flux, temperature, use of a separating layer between the waste and the drainage layer, saturated conditions versus unsaturated ones, etc. influence on the clogging of the drainage layer. So the contribution of each of aforementioned factors should be properly identified in order to preventing drainage layer clogging as well as adopting proper solution for this problem. The method of identifying the effective factors on the drainage layer clogging is considered as one of the most important challenges in the design and operation of engineering landfills. Installation of drainage layers under the waste piles makes almost impossible to measure the degree of clogging and determining its mechanism on a real scale. In the other hand, simulating the real conditions of landfills by using of small scale laboratory equipment faced with many limitations and errors which necessitates to simulate the real conditions of the landfill in the form of medium-scale pilots. So in this research, different medium-scale experimental columns were designed and built in order to evaluate the effective factors on the clogging of the drainage system in municipal waste landfills. The most important effective parameter on clogging of drainage system including the particle size and calcium carbonate concentration of the drainage layer materials were investigated to ensure the efficiency of the designed columns. The designed system could provide some advantages like applying different boundary conditions such as temperature and pressure, the possibility to recirculate leachate, as well as the ability to measure permeability of drainage layer. Long-term monitoring of this system indicates a relative decrease in permeability in all columns, which demonstrates clogging in the drainage layer. Furthermore, the samples selected at the end of the experiment and the observation of biofilm materials on the components of the drainage layer indicated the proper performance of the designed columns. It is obvious that the detailed analysis on the results of the clogging process and the measurement of more variables affecting this phenomenon are beyond the scope of the present study and its results are under investigation. However, the general procedure of permeability changes and visual observations showed that the designed system is successful in simulating real landfills.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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