Characterizations of Municipal Solid Waste Leachate using Column Experiments – Under Semi-Arid Conditions

Adnan Aish[1]* Thaer Abushbak [2] and Mohamed El-Nakhala[1]
1. Al Azhar University, Institute of Water and Environment, PO box 1277, Gaza, Palestine
2. Ministry of Agriculture, Central Laboratory for Water and Soil , PO box 4014, Gaza, Palestine
* E-mail of the corresponding author: aaish@alazhar.edu.ps

Abstract
The research aims to characterize the MSW leachate under the Gaza conditions (semi-arid climate), using column method to evaluate the temporal variations of the MSW leachate properties. Therefore three columns were used for extraction of MSW leachate. All the leachate samples were tested for several physical and chemical parameters, which are pH, E.C., TDS, NO_3^-, NH_3, Cl^-, Alkalinity, Hardness, Ca^{++}, Mg^{++}, K^+, Na^{++}, COD and BOD. The results demonstrated that the characterizations of the extracted leachate found to be in the highest ranges of contamination. However, the concentration of the contaminants increased with time up to a certain time, and then the concentrations decreased. The study concluded that the extracted leachate characterized, as a very high contaminated leachate. The results that derived from the study suggested that all the effort should be made in order to prevent the arrival of MSW leachate to the groundwater.
Keywords: Gaza Strip; MSW leachate; leachate characterization.

1. Introduction

The municipal solid wastes (MSW) are generated by the routine activities of everyday life, in addition to the unusual activities. The principal sources of MSW are homes, businesses, and institutions(Irene & Lo, 1996; Paris & Chih, 1997; & Zhao Jun, et al., 2013). The wide use of landfills poses the probability of groundwater contamination. Landfills have been identified as one of the major threats to groundwater resources (Castrillón et al., 2010). When leachate percolates to the groundwater and mixes with it, it forms a plume that spreads as the groundwater flows. The degree of contamination in the aquifers depends on the transport rate of contaminants and depository conditions at the site as the contaminants permeate through the soil media (Tubtimthai, 2003).

The characterizations of landfill leachate were investigated by several studies in the literature. The results showed high range of contaminants (AI-Muzaini et al., 1995; Al Sabahi et al., 2009; Alslaibi, 2009; Al-Yaqout & Hamoda, 2003; & Banar et al., 2006). However, the leachate characteristics and the range of contaminants didn't show a definite trend with age, type of waste dumped, thickness of waste layers, and hydrology of landfill (Al-Yaqout & Hamoda, 2003; Banar et al., 2006; Despina et al., 1999; & Nassar & Jaber 2007). While rains have a direct effect on the concentration of the contaminants in the MSW leachate, Banar et al., 2006 founded that, the concentration of pollutants in the leachate were higher during the dry seasons (summer season), this was due to the minimum amount of moisture percolates through the waste layers. While in rainy seasons (winter season) the water percolates through the landfill beds dissolve constituents and extract more quantities of diluted leachate. This revealed that the influence of climate has an effect on leachate generation and its characterizations. The seasonal variation of leachate generation pattern and the settlement of landfill indicated that, the highest degradation occurred during the rainy season, lowest degradation during the dry season; due to the lack of moisture (Shalini et al., 2012).

2. Methodology

Column method was used to simulate landfill conditions, in order to extract the MSW leachate. The experiment was performed under local conditions of Gaza City. The experiment took place at the roof of Al Azhar University, Gaza City, from the period of 20, June, 2011 to 19, August, 2011. Three columns made of PVC plastic 100 cm long, and 20 cm inner diameter were used to simulate the production of MSW leachate. A metal screen mesh at the bottom of each column was fixed; to withheld waste from dropping and allowing the leachate to flow out. A funnel was manufactured and mounted at the end of each column. A valve was installed at the end of each funnel to control both the leachate flow and collection. A gravel layer of 10 cm thickness was placed at metal mesh on the bottom of each column. The gravel particle size was between 10 mm and 4.46 mm. The aim of this gravel layer was to enable leachate drainage at the bottom of the column.

Samples of MSW were created and introduced into each column. The weight of each sample was 16.5 kg. This weight was calculated based on the density of Gaza Strip MSW, which is 300 kg/m3 in the container and 800 kg/m3 in the landfill, the average is 550 kg/m3 (Municipality of Gaza unpublished data). Since the volume of each column is 0.03 m3. Then the mass that should be introduced to each column can be calculated from the following equation:

$$W = D \times V \tag{1}$$

where:

W: is the weight of MSW, kg.

D: is the density of MSW, kg/m3.

V: is the volume, m3.

Each 16.5 kg sample was consisted of 70% organic matter, 8% plastic, 8% paper, 6% glass, 3% metals, and 5% others (Mor et al., 2006).

To prepare this MSW sample, 11.5 kg of organic matter (16.5 kg x 0.7), 1.32 kg plastic, 1.32 kg paper, 1 kg glass, 0.5 kg metal and 0.83 kg other materials, were used. All the categories were cut to small parts less than 2 cm, mainly the organic matter and the paper; in order to make the degradation of the waste easier and faster. Glass bottles and metals cans were crashed. All the categories were very well mixed manually, and introduced into the column without compaction. The sample of each column was prepared separately, 12 hours before the introduction to the columns. Then the waste was distributed uniformly in the columns. A clearance of one week was left between each column and another; for better control and better management of the experiment.

To simulate the annual precipitation, treated water was added on the top of the column. The amount of water that had been added was calculated according to the following equation (Tchobanoglous & Kreith, 2002).

$$L = P(1 - C) - E \tag{2}$$

where:

L = Depth of the leachate water, mm.

P = Precipitation, mm.

C = Leachate coefficient.

E = Evaporation, mm.

The leachate coefficient (C) in this study was 0.1 depending on the average daily precipitation about (11 mm) and the relationship given by Paris (Nassar & Jaber, 2007).

Depending on this, the amount of water to be added at the top of each column can be calculated as following:

$$W = L \times A \tag{3}$$

where:

W = water that will be added, L.

L = Depth of the leachate water, mm.

A = Area of the column surface, m2.

The preparation time of the leachate was 40 days for each column, in no raining season (summer). The information of leachate in Gaza Strip is mainly takes place during the wet season. The average rainy days in Gaza Strip is 40 days (based on unpublished data of Ministry of Agriculture 1985- 2010).

Based on this, water was added to the MSW column within 40 days to form the leachate. By applying the figures on table 1 to equation 2. The amount of leachate water L1 = 398.1 (1- 0.10) – 341.7 = 16.95 mm in raining season.

Table 1 The rainfall and evaporation at winter months

Month	*Precipitation (mm)	*Evaporation (mm)
December	132.4	79.5
January	142.1	66
February	86.9	92.4
March	36.7	103.8
Total	398.1	341.7

Since the experiment was carried out during the summer time and evaporation is significant during this period, the amount of evaporation was added to the leachate water (L1).

Once again by applying equation 2, with the figures in table 2, the amount of leachate water evaporated during the summer season will be:

L2 = 3 (1 – 0.1) – 301.2 = - 298.5 mm in summer season.

(The negative sign indicates that this is evaporated water).

So the total head at water to be added to each column is:

L = 16.95 – (- 298.5) = 315.5 mm

The surface area of the column (A) was 0.03 m2.

By applying equation 3:

The amount of water (W) that will be added = 315.5 x 0.03 = 9.5 L

Table 2 The rainfall and evaporation at experiment months

Month	*Precipitation (mm)	*Evaporation (mm)
June	2	152.7
July	1	148.5
Total	3	301.2

The 9.5 L of water were distributed for four equal patches during the experiment period (40 days). Each patch of water was about (2.5 L)and added every 10 days. The leachate in each column was retained in the columns until the end of the experiment. The retention of the leachate in the column was expected to enhance the degradation of the organic matter and to compensate some of the short period of the experiment.

Samples from the leachate were taken for testing every 10 days. 50 ml samplers (centrifuge tubes) were used for the collection of the samples. The samples were transferred immediately to the laboratory of Al Azhar University and to the public health laboratory in the ministry of health for analysis. The leachate was categorized for different physical and chemical parameters. The parameters are:

- pH, Electrical Conductivity (E.C.), and Total Dissolved Solids (TDS).
- Nitrate (NO_3^-), Ammonia (NH_3), Sulfate (SO_4^{--}), and Chloride (Cl^-).
- Calcium (Ca^{++}), Magnesium (Mg^{++}), Potassium (K^+), and Sodium (Na^+).
- Total Alkalinity as calcium carbonate ($CaCO_3$) and Total Hardness as ($CaCO_3$).
- Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and BOD/COD ratio.

All the analyses were conducted according to the Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA).

3. Results and Discussions

The characteristics of the prepared MSW leachate under the conditions of Gaza Strip found to be in very high concentration, as demonstrated by table 3.

It is apparent that the pH for the leachate decreased with time. It was reported to be 7.09 after 10 days, and became 5.4 after 40 days as shown in table 3. There is almost general consensus that during the initial stages of the landfill the pH values are quite low. Such behavior was observed also by (Aik et al., 2010 & Castrillón et al., 2010). The degradation of carbohydrate in the leachate to form fatty acids is the main contribution in the pH reduction (AI-Muzaini et al., 1995).

As expected, the TDS and E.C. were extremely high. Moreover, the results demonstrated that TDS and E.C. increased at the first 30 days. An obvious decreasing was detected in the last 10 days as shown in figure 1. The relative high values of TDS and E.C., can be attributed to the presence of high amount of inorganic materials (Al-Yaqout & Hamoda, 2003; Liu, 1999 & Tubtimthai, 2003). However, the decreased concentration of the TDS after the 40 days reflected the effect of the dilution that could occurred by the continues addition of water ; this is in line with what stated by (Paris, 1996; Tchobanoglous & Kreith, 2002 & Tuffaha, 2006). Admittedly, the fluctuating in TDS values prevailed that the concentration of the inorganic matter can't be controlled by obvious rules in this short period of the experiment.

Table 3 Variations in leachate characteristics in relation to time

Parameter	Unit	10 days	20 days	30 days	40 days
pH	-	7.09	6.51	6.49	5.4
E.C	s/cm	31.56	32.36	44.0	27.0
TDS	g/l	19.57	20.06	27.28	16.74
NO_3^-	g/l	2.03	1.9	1.62	1.18
NH_3	g/l	0.11	0.33	0.44	0.55
Cl^-	g/l	2.34	2.34	2.06	2.86
Alkalinity	g/l as $CaCO_3$	9.48	9.48	6.56	7.78
Hardness	g/l as $CaCO_3$	12.38	13.8	11.67	14.58
Ca^{++}	g/l	3.72	3.7	3.35	2.68
Mg^{++}	g/l	0.75	1.1	0.8	1.92
K^+	g/l	1.92	2.04	2.0	1.76
Na^+	g/l	1.12	1.12	1.2	1.2
COD	g/l	45.2	59.07	66.96	49.0
BOD	g/l	22.5	41.0	43.25	17.5
BOD/COD	-	0.5	0.7	0.65	0.36

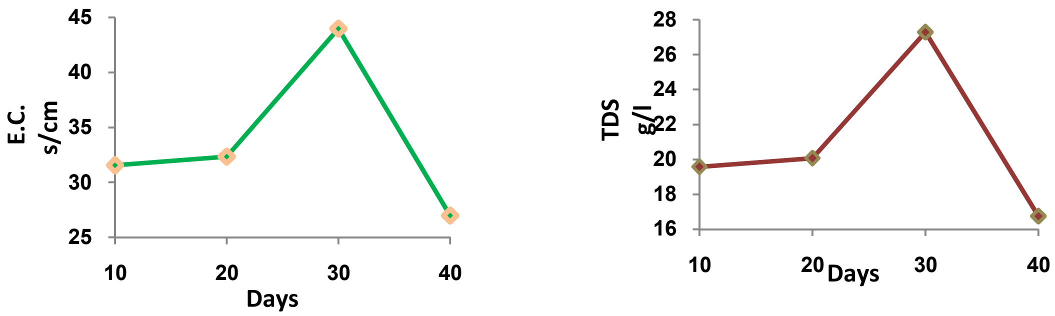

Figure 1 The variations in E.C. and TDS of extracted leachate as a function of time

As it is apparent in table 3, the levels of concentration of BOD and COD were relatively high. Generally, young age leachate will be high in BOD and COD, as a result of organic waste decomposition. This was similar to what demonstrated by (Al Sabahi et al., 2009; & Al-Yaqout & Hamoda, 2003). The concentration of BOD increased with the passing of time till the 30 days. While during the last 10 days the concentration decreased drastically. A decline in BOD concentrations generally referred to the reduction in organic contaminants. The COD concentration in the leachate shows a similar behavior to that of BOD as shown in figure 2.

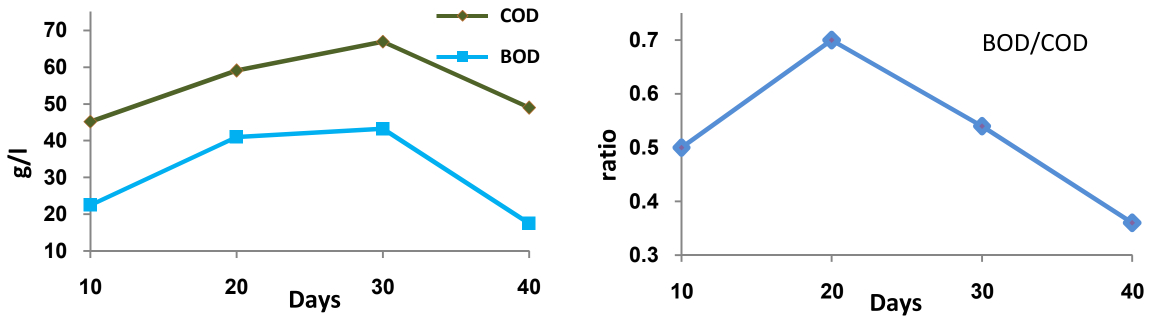

Figure 2 The variations in COD and BOD and BOD/COD of extracted leachate as a function of time

As BOD decreased faster than COD in the last 10 days, then the ratio of BOD/COD was decreased, figure 2. However, the ratio varied from 0.7 to 0.36 as demonstrated by table 3, which was an indication that the organic matter was readily degradable (Banar et al., 2006 & Castrillón et al., 2010).

The NH_3 was relatively high 0.11 g/l at the first 10 days and it started to increase with time constantly till it reached 0.55 g/l at the 40 days. In contrary to this, there was an obvious decreasing in the NO_3- concentration all the time. It reached 1.18 g/l after 40 days as it was extremely high 2.03 g/l at the first 10 days, figure 3. The reduction of NO_3- can be attributed to anaerobic conditions which might be presented in the column (Shalini & Kurian, 2012).

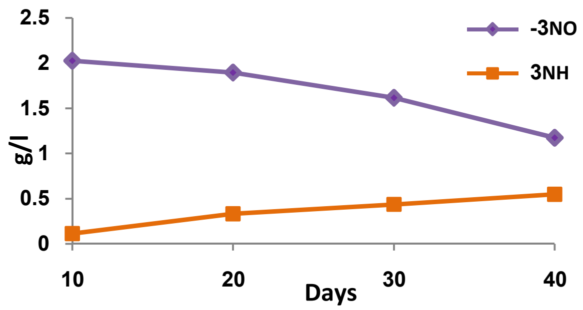

Figure 3 The variations in NO_3^- and NH_3 of extracted leachate as a function of time.

4. Conclusions

Columns investigation experiments were performed in order to investigate the characterizations of MSW leachate. Three columns were used for the extraction of the MSW leachate. Each column was monitored for 40 days. Results showed that the concentration of MSW leachate differs from landfill to another, even with the same MSW compositions. The prepared MSW leachate concentration can be characterized as a very high contaminated leachate. Time plays an important role in affecting the leachate concentration. The concentration of the contaminants in extracted leachate, generally had increased with time up to a certain time; then it started to decrease. The properties of the contaminants played an important role in the attenuation of the contaminants themselves.

References

Aik H., Hamid N. and Yung T. (2010). Characterizationof Acetogenicand Methanogenic Leachate Generated from a Sanitary Landfill Site. World Academy of Science, Engineering and Technology 67.

AI-Muzaini S., Mirza U. andMuslmani K.(1995). Characterization of Landfill Leachates at a Waste Disposal Site in Kuwait. *Environment International*Vol. 21, No. 4, pp 399-405.

Al Sabahi E., Abdul Rahim S., Wan Zuhairi ben Wan Yacob, Al Nozaily F. and Al Shaebi F. (2009). A study of surface water and Groundwater Pollution in Ibb City Yemen. *Electronic Journal of Geotechnical Engineering.* vol. 14 Bund. F.

Alslaibi T.(2009). Evaluating the Impact of Landfill Leachate on Groundwater Aquifer in Gaza Strip Using Modeling Approach. (Master Thesis) *The Islamic University* – Gaza – Palestine.

Al-Yaqout A. and Hamoda, M. (2003). Evaluation of Landfill Leachate in Arid Climate, a Case Study **.***Environment International* 29: 593-600.

APHA (1995).Standard Methods for Examination of Water and Waste Water, 20thed, *United States of America, American Public Health Association*.

Banar M., Ozkan A. and Kurkcuoglu M. (2006). Characterization of the Leachate in Urban Landfill by Physicochemical Analysis and Solid Phase Micro extraction –GC/MS. *Environmental Monitoring and Assessment* 121: 439-459.

Castrillón L., Y. Fernández-Nava, M. Ulmanu, I. Anger, E. Marañón (2010). Physico-chemical and biological treatment of MSW landfill leachate. Waste Management 30: 228–235

Despina F., Achilleas, P. and Maria, L. (1999).A Study on the Landfill Leachate and Its Impact on the Groundwater Quality of the Greater Area. *Environmental Geochemistry* and Health 21:175–190.

Irene M. and Lo C., (1996). Characteristics and Treatment of Leachate From Domestic Landfills. *Environment International* Vol. 22, No. 4, pp. 433-422.

Liu D. (1999). Environmental Engineers Handbook. *CRC Press LLC.*

Mor S., Ravindra K., Dahiya R. and Chandra A.(2006). Leachate Characterization and Assessment of Groundwater Pollution near Municipal Solid Waste Landfill Site. *Environmental Monitoring and Assessment* 118:435-456.

Nassar M. and Jaber A.(2007). Assessment of Solid Waste Dump Sites in Gaza Strip Environment Quality Authority (EQA) and Japanese International Cooperation Agency (JICA).

Paris H. (1996). Assessment of Leachate from Sanitary Landfills : Impact of Age, Rainfall, and Treatment. *Environment International*, Vol. 22, No. 2 pp. 225-237.

Paris H. and Chih Y.,(1997).Investigation in to Municipal Waste Leachate in the Unsaturated Zone of Red Soil. *Environment International*, Vol. 23, No. 2, pp. 237-245, 1997.

Shalini S. Sri, Kurian Joseph (2012). Nitrogen management in landfill leachate: Application of SHARON, ANAMMOX and combined SHARON–ANAMMOX process. Waste Management 32: 2385–2400

Tchobanoglous G. and Kreith F. (2002). Handbook of solid Waste Management second edition. McGraw-HILL.

Tubtimthai O. (2003). Landfill lysimeter Studies for Leachate Characterization and Top Cover Methane Oxidation. (Master Thesis) *Asian Institute of Technology. School of Environment, Resource and Development*, Thailand.

Tuffaha R.(2006). Impacts of Solid Waste Leachate on Soil and its Simulation to Groundwater at Nablus Area. (Master Thesis) *Al-Najah National University* Nablus, Palestine.

Vasanthi P., Kaliappan S., and Srinivasaraghavan R.(2008). Impact of Poor Solid Waste Management on Groundwater. *Environ Monet Assess* 143:227-238.

Yildiz E., Unlu K. and Rowe R. (2004).Modeling Leachate Quality and Quantity in Municipal Solid Waste Landfills. *Waste Management and Research* 22-2:78-92.

Zhao Jun, Xue-Qin Lu, Jing-Huan Luo, Jian-Yong Liu, Yun-Feng Xu, Ai-Hua Zhao, Feng Liu, Jun Tai, Guang-Ren Qian, Bin Peng (2013). Characterization of fresh leachate from a refuse transfer station under different seasons. International Biodeterioration & Biodegradation 85: 631-637

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Recent conferences: http://www.iiste.org/conference/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar