Investigation of Characteristics Landfill leachate using Large Scale Lysimeter under Anaerobic Conditions

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K E Y W O R D S

Physiochemical characteristics of leachate MSW, Leachate, Moisture content ,Temperature

A B S T R A C T

Landfill behavior is dependent on the composition and characteristics of the region's municipal solid waste (MSW) and environment conditions. In landfills that are difficult to understand, MSW undergoes several complex mechanisms such as physical, chemical, thermal and biological processes throughout its lifespan. In the present research, by setting up an anaerobic reactor, an attempt was made to understand such complex processes. The reactor was monitored for a total of 270 days under laboratory conditions, and the results obtained from the experimental program are presented and discussed in this paper. The program involves the monitoring by laboratory experiments of moisture content, pH, temperature, as well as physic-chemical characteristics of the leachate samples. The pH values observed were in the 5.8-7.9 range and indicate the achievement of the optimal condition for MSW degradation. MSW's average volumetric moisture content and temperature were 53.03% percent and 30.7 C° respectively, indicating favorable conditions for microorganism growth. The results described in this paper could potentially be used in landfills to predict MSW behavior. The research also allows planners and engineers to consider the complex mechanisms for planning and running landfills efficiently for sustainable waste management.

1. Introduction

Landfilling is the predominant disposal method in most of the countries because it is the most feasible and economical alternative. Sanitary landfill is a process in the solid waste management system. It can be defined as ‘‘a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day’s operation or at such more frequent intervals as may be necessary. Landfills pose a major environmental problem in which various types of hazards such as gas and leachate are generated during landfill operations [1].
MSW typically consists of metals, glass, plastics, paper, wood, organics, mixed categories, and composite products. MSW's composition varies with region and time, too. The rate of organic content degradation and decomposition in landfills depends on the conditions favorable for MSW's anaerobic bacterial growth. Moisture content, temperature, pH, nutrients, and oxygen content are

the conditions or factors used. It is difficult to understand the variance in these critical variables, which is important to predict the overall time needed for the complete decomposition of organic content and stabilization of landfill. This helps to prepare and implement waste management techniques with regard to the future usage of additional space for MSW land filling.

The anaerobic environment prevails due to the absence of oxygen content in the landfill, Landfill produces large amounts of leachate and landfill gasses (LFG) during the period of anaerobic degradation and decomposition that are hazardous to the environment if released untreated.

The conventional engineered landfill usually consists of the bottom liners system and the top cover system of the MSW. The geotechnical characteristics of various containment system components affect the efficiency of the entire landfill. Excess rainfall penetration creates huge quantities of leachate. This may have a direct effect on the performance of the liner system and the overall stability of the landfill. The elevated temperature in landfills contributes to desiccation and cracking, as well as reducing the life of liner system geo-synthetic materials. It is important to model and assess the landfill designs for successful MSW management to determine the behavior of the landfill system in relation to the climatic conditions of the area.

Literature

Moisture Content

Moisture content is one of the critical factors for the successful degradation of MSW. The moisture content of MSW in landfills depends on the region's age, waste composition, degree of compaction, amount of organic content and precipitation infiltration rate [2]. Initially, after the MSW reaches its field capacity, moisture content is maintained by the surface tension forces and excess liquid drains out of the system as media.

Conventional sanitary landfills are operated to reduce the amount of moisture that infiltrates the waste (the concept of dry cells), while bioreactor landfills are designed and operated to increase the level of waste moisture in the landfill to improve the process of biodegradation [3].

Temperature

Another important factor that influences microbial growth and its activity for effective degradation of refuse is the temperature in MSW. An optimal range for microbial activity will be the temperature in the 30 ± 4 C ranges [4]. The placement and age of the waste, the depth and location of the waste and the available moisture have a direct effect on the temperature [5]. MSW's thermal conductivity properties also contribute to heat transfer to the immediate overlay cover and the underlying liner system. This often increases the overall hydraulic conductivity of the containment system [6] and, by reducing its service life [7], adversely affects the integrity of different components. The study [8] found that the average peak temperature at the base of a landfill cell was 60 and 57 C at 4 m above the liner system. MSW temperatures in landfills in North America range from 19 to 60 C, 12.9 to 17.5 C in the cover system and from 14.3 to 23.3 C in the 1 and 2 m depths of the cover system [9], respectively. The temperature can exceed 30, 60 and 20 C, respectively, for the liner system, MSW and cover system. Elevated temperature in landfills decreases the service life of liner system by increasing the rate of antioxidant depletion from HDPE geomembrane [10]. [11] Also stated that the temperature of the liner system ranges from 30 to 40 C. The seasonal temperature variation in the cover system varies between 0 C (during winter) and 30 C (during summer) [12].

Objectives

In the present research, an attempt was made to investigate the behavior of a conventional landfill system under the influence of rainfall using a large-scale anaerobic reactor under laboratory conditions. To this purpose, an anaerobic reactor was set up to monitor the complete degradation of organic or decomposable matter. Furthermore, this paper presents the results of the experimental program which includes physiochemical characteristics of leachate samples, seasonal variations in moisture content, and temperature.

2. Experimental Program

I. Pilot Scale Lysimeter Design

Pilot lysimeter (PL) was installed and operated as a prototype of a conventional landfill system. A landfill system of size 1500 mm width, 1800 mm length and 1500 mm height with a total volume of 4.05 m^3 was fabricated in the laboratory to study and understand the behavior of landfill system. The set up was made of 6 mm wall thickness acrylic sheets with a slightly sides sloped. The system consists of MSW layer between the liner system and cover system. A 150 mm diameter drainage pipes have longitudinal slope 1% to reduce sedimentation and allow adequate flow capacity. Leachate will be collected or drain through 7 mm pipe perforations in six rows, and spaced 100 mm center to center.

The specification for the landfill liner and cover system was downscaled for the laboratory set up [13].The specifications include 1200 mm thick cover system and 1050 mm thick liner system. Accordingly, the cover system and liner system were reduced to 14.66 % and 28% of the above mentioned specifications, respectively. Considering waste thickness of 5 m in the field, it was downscaled to 650 mm (15%) for the purpose of laboratory investigations. The downscale ratio was chosen based on the height of the rector. In order to avoid clogging of drainage layer from soil particles and mixing of materials of different layers, a geo-grid of 1 mm thick was placed as a separation layer at the interface of top cover, MSW layer and bottom liners system. The system was also made air tight using silicone gel to avoid leakage of leachate. Placement and properties of various components of the system are explained in the subsequent sections. Figure (1) displays the pilot scale lysimeter filling and components.

At the liner of the pilot system, a 200 mm thick gravel layer with particle sizes between 16 and 12.5 mm was placed to allow easy flow of leachate into the leachate collection tank. A perforated plate of 10 mm thick was placed just above the gravel layer to separate the liner system and the leachate collection layer. The liner system 600 mm thick consists of a drainage layer and compacted clay layer. The locally available clay soil was used as a barrier material in the liner system. The compaction of clay (thickness 400 mm) was performed to achieve the required density at specific water content.

Municipal solid waste (MSW) composition compatible with composition of MSW in point of generation (households) were provided from the surrounding area, which is known by its high organic content. Physical composition of the MSW was studied on the dry MSW samples and is presented in the Table (1). The waste was introduced into the pilot scale lysimeter after shredding into suitable size. The system was filled with 842.5 kg of MSW to a total thickness of 650 mm.

Furthermore, lysimeter was provided with five sides ports for MSW samples and for thermocouples sensors installed (temperature monitoring) and moisture monitoring. Layers of compacted clay were provided at the top of lysimeter as a cover for regular distribution of rainfall in addition to protect the outdoor environment from lysimeter effects such as odour or other pathogen effects.

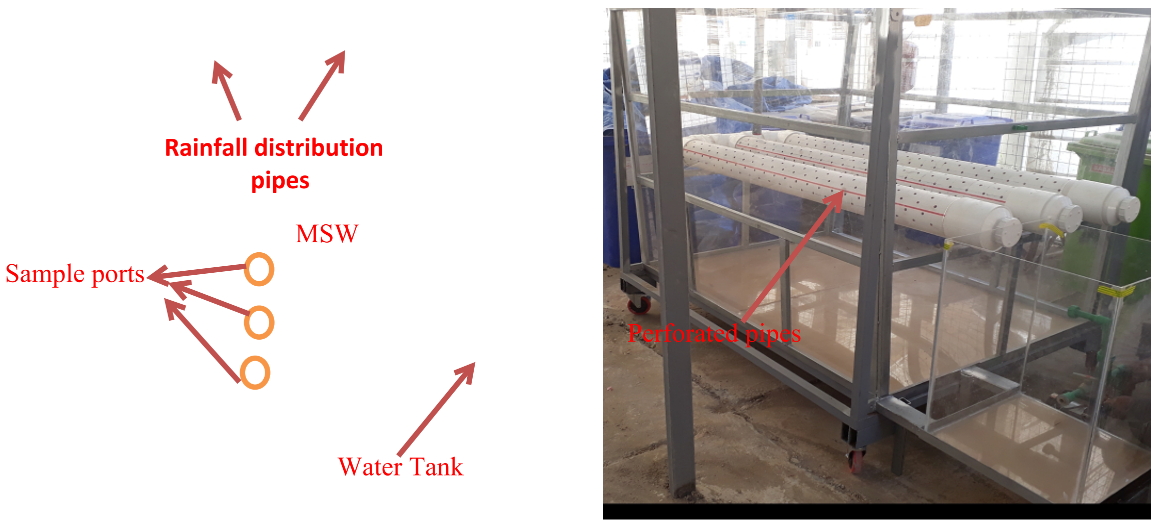

Figure1: Pilot scale lysimeter filling and instruments

Table 1: Composition of average municipal solid waste (MSW) of residential areas

	Percent by weight			Average
Waste Composition	**Low income**	**Middle income**	**High income**	**%**
Food waste	65.4	68.8	69.8	68
Plastics	6.9	7.9	7.4	7.4
Metals	4.8	6.1	6.5	5.8
Glass	2.2	2.4	2.3	2.3
Paper	4.9	5.3	5.4	5.2
Textile	3.2	2.3	3.8	3.1
Others	12.6	7.2	4.8	8.2
Total	**100**	**100**	**100**	**100**

The drainage system in the liner lysimeter system was laid on the gravel layer. The draining pipes system typically consisted of a series of high density polyethylene HDPE perforated pipes 150 mm in diameter connected together with lateral pipes, each pipe was punched with 7 mm diameter openings to drain the leachate within the pore and typically pumped or gravity- flowed to a holding tank. The manifold pipes were ended with a controlling valve and a faucet for sampling and draining. At the top of the lysimeter drainage system, a geogrid layer was installed to prevent clogging by suspended solids from leachate.
The reactor has been made leak proof and facilitated by outlet valves to collect leachate provided by MSW degradation. Leachate was collected regularly through an outlet valve provided at the bottom that was kept open throughout the monitoring period and reported the amount of leachate. Leachate samples are obtained on a monthly basis and stored at room temperature in a dark place in capped plastic bottles until they have been checked.
Also, rainfall distribution system consists of a small tank of 120 liter capacity and the effective capacity 90 liter was placed beside the experimental unit as a water reservoir to simulate the rainfall. A measured amount of rainfall was added through the inlet valve provided at the top of the experimental unit, as input to the system. Lysimeter was provided with a water sprinkler to disperse water uniformly over the top area of the lysimeter.

3. Results and Discussion

This section presents and examines the results of the monitoring of the large-scale anaerobic reactor for up to 270 days from the beginning of the program (from 1st August 2018 to 15th May 2019). The reactor was set up to be monitored continuously until the organic content in the filled MSW degrades completely and reaches the stabilization point.

I. Simulation of Rainfall and Leachate Analysis

The amount of rainfall was simulated from actual rainfall data in Baqubah city. The data recorded the amount of rainfall collected by the Water Resources Directorate to simulate lysimeter conditions, assuming that all the amount of precipitated rainfall was percolated through the cover layers of simulated landfills, the amount of precipitated rainfall in mm converted to discharge applied to top surface of lysimeter according to following equation [14].

$$Q = a * d * R \qquad (1)$$

where:
Q= Simulated discharge of rainfall applied, m^3/day,
d= intensity of rainfall, mm/day,
a= lysimeter surface area, m^2, and
R= Factor for correction (10^{-3} mm/m).

A plot of observed monthly total natural rainfall in the region during the monitoring period is presented in Figure 2. It was observed that the region has received maximum rainfall of 54.3 mm in February 2019 and no rainfall was observed during July, Augusts, and September 2018.
The observed amount of rainfall was simulated to the reactor on a monthly basis depending on the day of rainfall event. The quantity of leachate generated was collected and measured before the simulation of the next rainfall. Make up showers simulating real intensity in millilitre per month were applied at the top of the pilot scale lysimeter.

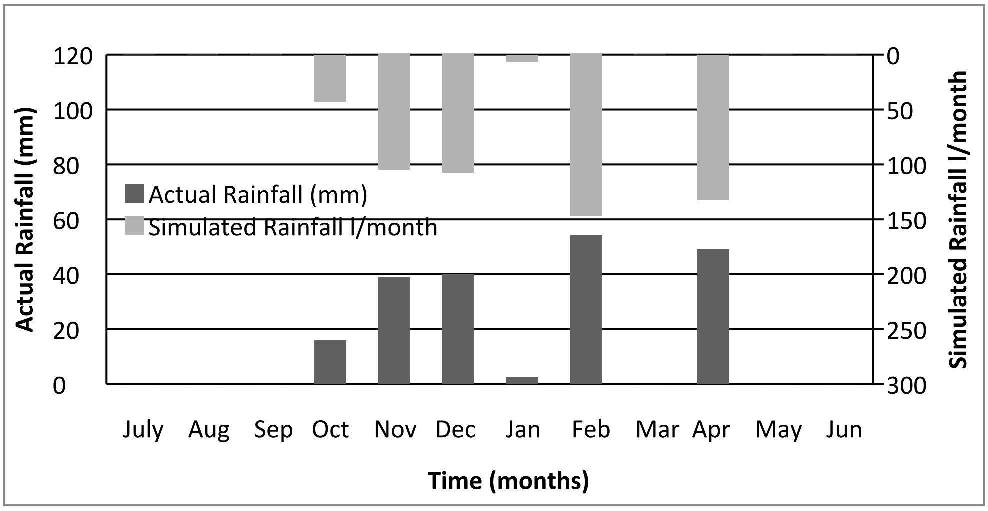

Figure 2: Simulated rainfall applied to landfill simulator

Leachate samples were collected from the lysimeter during the monitoring period of 270 days and stored before analysis in the refrigerator at a temperature of about 4°C in order to reduce the possibility of significant changes in the concentration of the contaminants due to the action of organic matter in the leachate. These samples were then analyzed in the Central Service Laboratory at Baghdad University to obtain the concentration of the dominant parameter that would be used to examine the phenomenon of contaminant transport through the GCLs. The physiochemical characteristics were analyzed according to standard methods for the examination APHA (1965) which include pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), and chemical oxygen demand (COD).

PH

The most significant parameter affecting leachate concentration in MSW landfill is considered to be the pH [15]. PH from the point of view of [16] was considered an indicator of leachate aggressiveness, where metal dissolution is enhanced at low pH which is one of the characteristics of young leachate from landfill [17]. MSW contains soil and organic matter which have significant sportive capacity, especially at high pH [18]. Figure (3) show the variation in pH of pilot scale lysimeter.

The obtained results showed that the initial pH value of leachate sample was 7.83. PH is controlled principally by a series of chemical reactions. PH values decreased later to 5.8 due to acid accumulation because of organic matter hydrolysis producing organic acids as end products of acidogenensis bacteria metabolism. While pH kept on fluctuating and this may be attributed to dilution effects due to rainfall activity. Later, pH began to increase gradually with drops in hot weeks during dry season followed by a gradual increase in value for the rest of the study period. [19] Stated that such behavior of varying pH values reflects the transition between phases in sanitary landfill. PH value began to increase gradually to reach maximum value recorded of 7.9 in stabilization layer. Such increasing in pH values indicate to optimum condition for degradation of refuse and also methane production phase concurrent with hydrogen, carbon dioxide and VFA reduction [20]. PH values later take a consistent pattern with values more than 7.0.

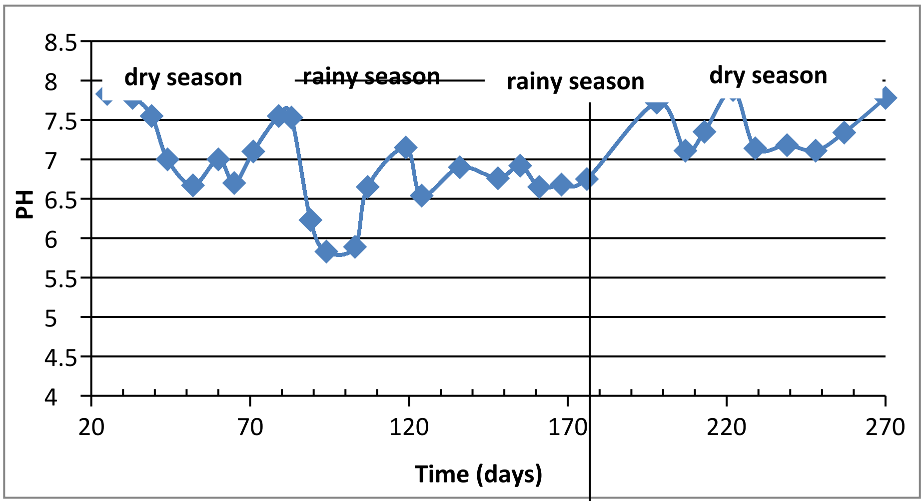

Figure 3: Variation of pH in leachate samples for landfill lysimeter

Total Dissolved Solids (TDS)

The variation in total dissolved solid (TDS) and total suspended solid (TSS) in leachate in relation to the increasing of elapsed period for of entire lysimeter operation in pilot scale lysimeter are presented in Figure (4). The dissolved solids in leachate mainly comprises of calcium, magnesium, sulphate, chloride, potassium and bicarbonates. The results showed reduction in TDS from 9,440 to 8,192 mg/L with increasing time. The observed reduction in TDS values is due to the microbial activity [21].

In next rainy days, the increment in TDS values were noticed due to leaching of dissolved solid that result from degradation enhancement in high moisture condition. Here, it is interesting to note after that, in dry season, the concentration of TDS also began to decrease and it was dropped to 3200 mg/l till the end of study.

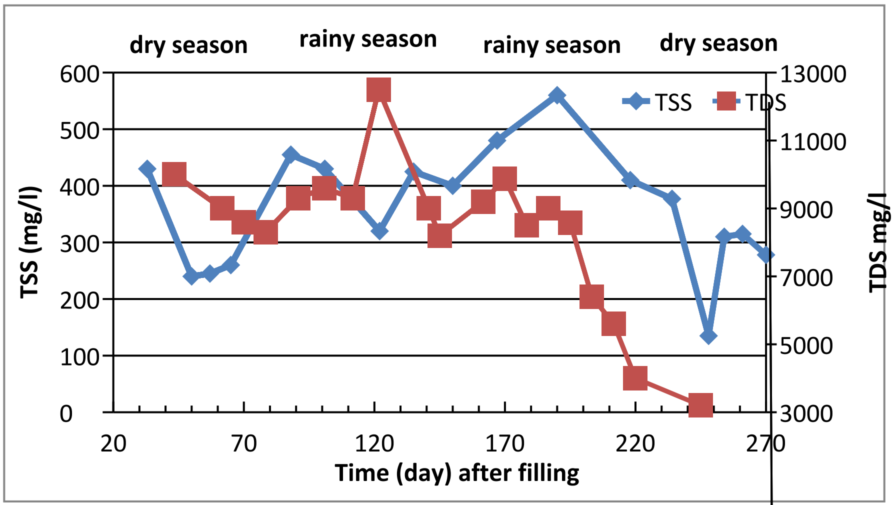

Figure 4: TSS and TDS in leachate samples of lysimeter

Electrical Conductivity (EC)

This parameter refers to the ability of leachate to carry electric current based on the concentration of ions. The variation in EC of the analyzed leachate samples showed reducing trend over the monitoring period as presented in Figure (5). During the initial period of the experiment, the value of EC was observed to be 12.8ms/cm then increased to 15.4 ms/cm after 83 day of filling. The values of EC fluctuate in pattern of next days to reach maximum value 17.6 ms/cm in day 119 of filling during rainy season. While in run two at end of experiment, EC significantly started to decrease in dry season to reach minimum value 6.2 ms/cm with increasing age of refuse. The observed reduction in EC indicates the solubility of salts in leachate.

Chemical Oxygen Demand (COD)

This refers to the amount of oxygen needed to degrade the organic content. Organic matter released from landfill lysimeter indirectly reflects landfill stabilization and assessed by the COD concentration values measured [22]. As the overall leachate strength determined by COD [23], this parameter was monitored weekly for the whole experiment duration for lysimeter.
Figure (6) displays the variation of COD in relation to the increasing of elapsed period in pilot scale lysimeters (run one and run two). COD was initially about 1600 mg/l and increased later in fluctuated pattern with the range (1625-1800) mg/l during the first 2 weeks from the waste placement. This increase in COD indicates deficiency in the oxygen for the degradation of organic content in the MSW and the attainment of anaerobic degradation, and decreased in values for the next following days. COD values dropped to 1150 mg/l on day 70, but increased again to reach maximum value on day 110 in rainy season with 2300 mg/l, dropping were noticed in COD concentration to 1250 mg/l on day 132 during heavily raining week concurrent with high production of leachate, while in run two COD concentration values fluctuated in the period of operation in rainy season. Such behavior may be attributed to dilution effect on COD concentration. COD values kept on decreasing gradually till the end of the experiment during the summer season to reach minimum value of 670 mg/l. Since variations in the quality of leachate with age should be anticipated during most of the landfill life because organic matter will continue to deteriorate (degradation) [24], the steady decreasing trend was observed by [25]. COD decreases with the increasing age of the landfill due to the initially biodegradable nature and washout of MSW due to rainfall [2]. In addition, due to rainfall events, COD seemed to be diluted and thus the concentration of COD was reduced [26].

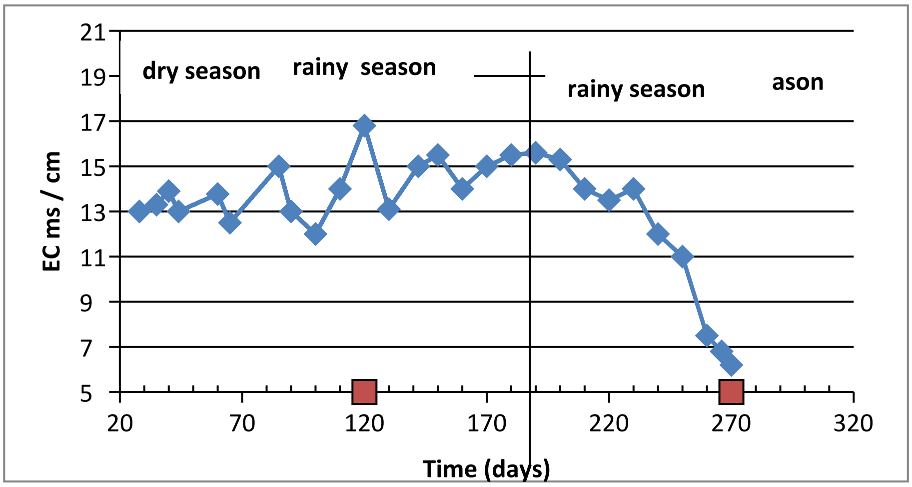

Figure 5: EC variation in leachate samples

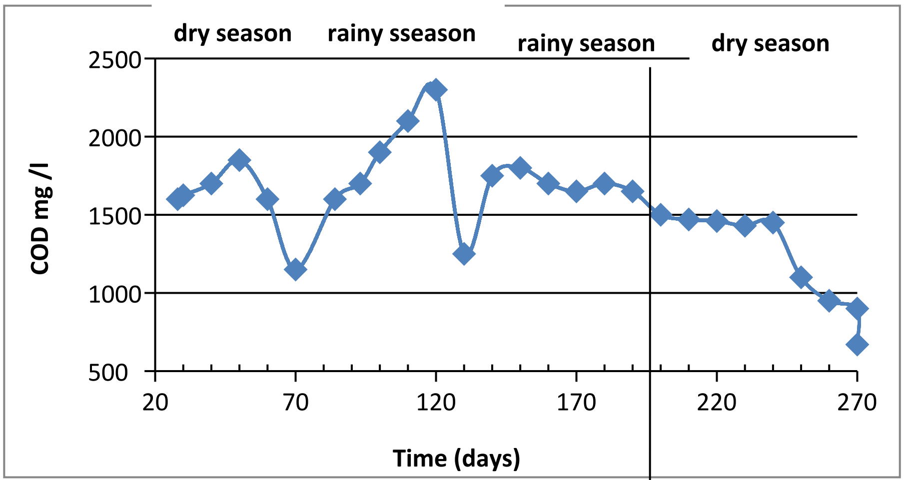

Figure 6: Variation of Chemical oxygen demand (COD) concentration in leachate samples

Contrary to [16], which stated that the COD was highest during the summer and is diluted during the rainy season, this would be logical if the dumping of waste, began in experiments in the dry season instead of the rainy season.

Moisture Content

The variance in the volumetric moisture content (%) of the landfill lysimeter was measured on a regular basis during the monitoring period by means of sensor placement. The monitoring of moisture content began from 1st August 2018, after 15 days of placement of MSW. The variation in the moisture content of MSW at three levels is presented in Figure (7). The top zone is 25 cm, the middle zone is 50 cm and the bottom zone is 75 cm from the top surface of the filled MSW. The results showed that the moisture content in the upper zone was considerably higher than in the middle and lower zones. This can be attributed to the percolation of simulated rainfall into the MSW under gravity through the cover system and its vertical downward movement.

The water movement fully saturates the top zone along the preferential flow path, and residual water moves down to the subsequent zones after reaching its field capacity.

Also, significant variation in moisture content was observed in the bottom zone due to the continuous cycle of saturation and outflow of leachate from MSW to the bottom liners system. The observed maximum values of moisture content are 57.2% at the top zone, 50.3% at the middle zone and 51.6% at the bottom zone of the MSW during the rainy season after 40 days of filling. The observed lowest moisture content value of 38.4% at the bottom zone on 78 days could be attributed to the vertical and/or lateral movement of liquid along the preferential flow paths creating

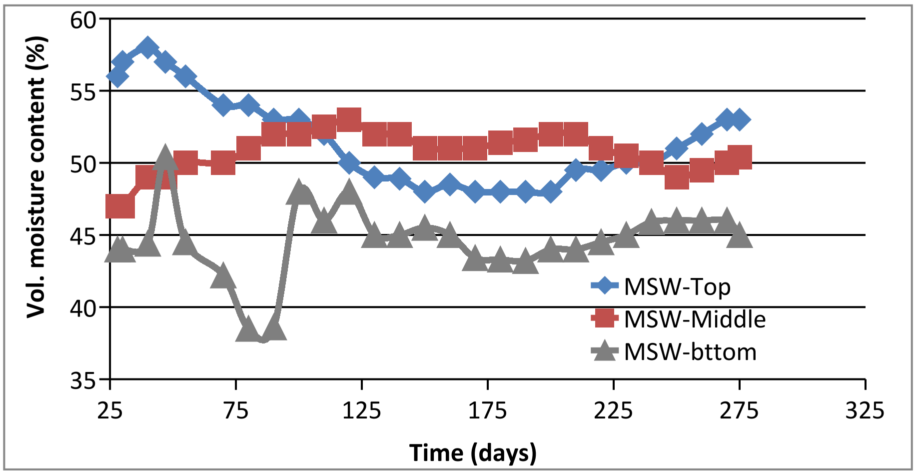

Figure 7: Variation in moisture content of MSW in the lysimeter

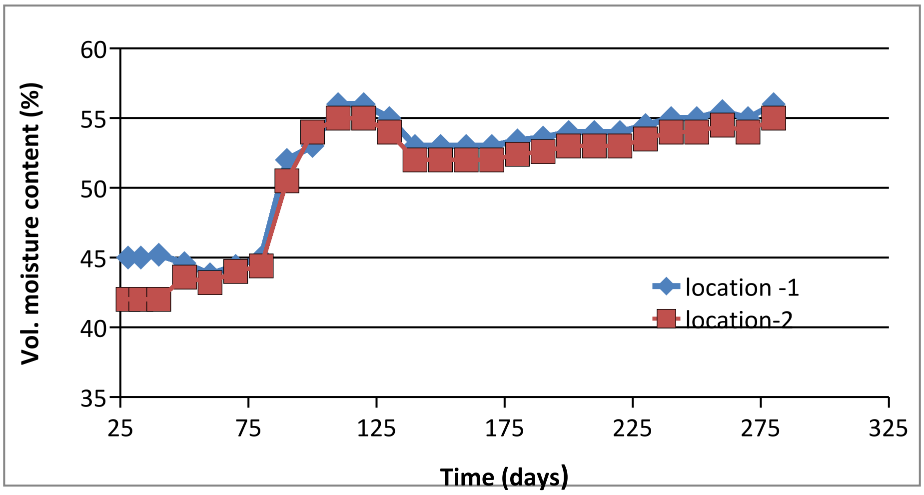

Figure 8: a Variation of moisture content in bottom liner of lysimeter

unsaturated zones and suction. The increase in moisture content can be attributed to the generation of leachate during the summer season though there are no rainfall events.

The results obtained from the two moisture content sensors which were placed in the bottom clay liner system are shown in Figure (8). The obtained results showed that the moisture content increased abruptly to 56.2% during the rainy season and reduced immediately after the season. Again, the moisture content increased gradually to 55%. However, significant variation at two locations was observed only during the peak rainy season and less variation in the non-rainy season. The observed maximum moisture content value at location-1 and at location-2 was 56.2 and 55.1% respectively. The obtained results are indicative of spatial and seasonal changes in preferential flow path for leachate migration in containment system.

Temperature

Temperature is considered one of the variables of operation and condition (e.g., composition of waste and availability of moisture) [27].Waste temperature in landfill simulator was mainly affected by the variation of ambient temperature. The variation in temperature was monitored by means of two thermocouples placed in the MSW layer (upper and lower) as well as in bottom liners system (middle level) for pilot scale lysimeter.

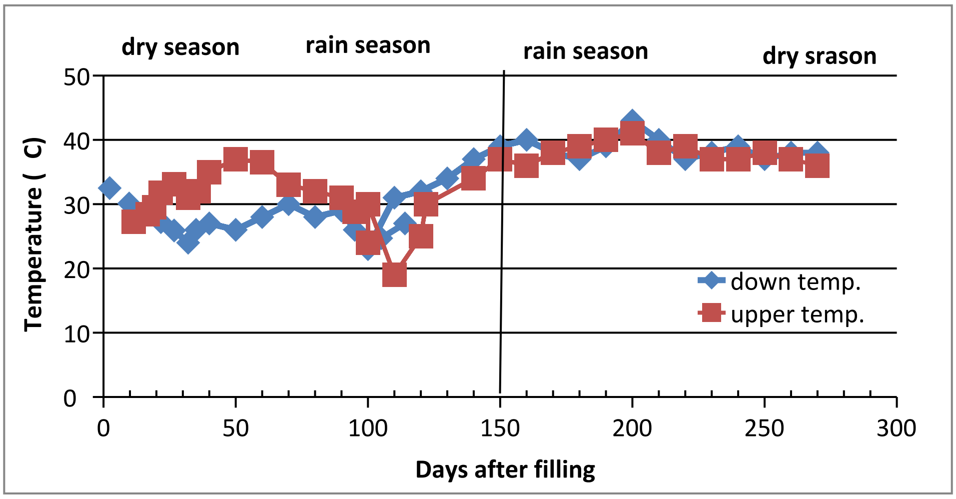

Figure 9: a Variation of temperature in the MSW at two depths (up and down) measured

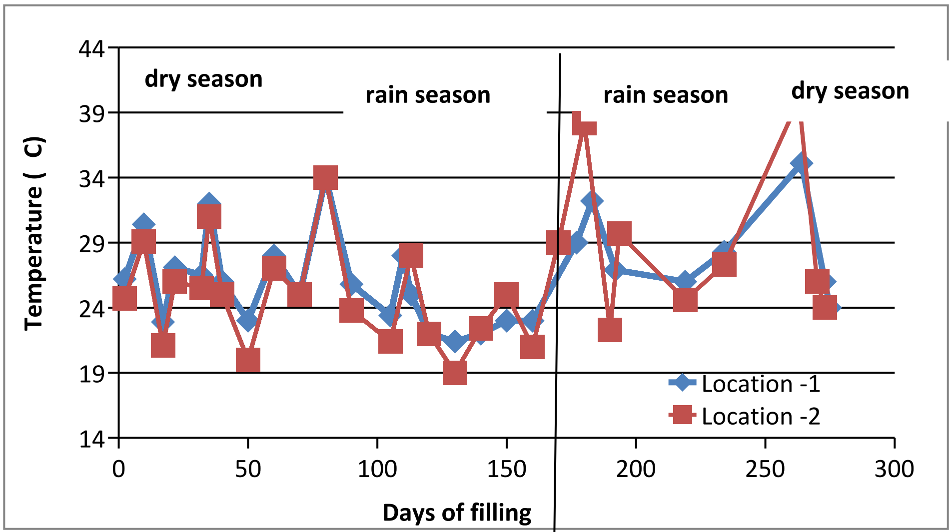

Figure 10: a Variation of temperature in the bottom system of the lysimeter

Table 2: Variation of temperature in MSW and bottom liners system

Layer	**Zone**	**Temperature**								
		Peak rainy season			Non rainy season			Monitoring period		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
MSW	Top	20.9	28.8	37.2	36.0	38.05	43.1	18.4	30.7	43.1
	Bottom	18.4	27.0	32.8	22.9	28.9	35.0			
	Avg.	19.6	27.9	35.0	23.0	29.2	37.5			
BCL	Location. 1	21.2	26.7	39.9	22.6	26.8	35.1	19.6	29.9	41.3
	Location. 2	19.6	26.3	35.4	21.2	28.2	41.3			
	Avg.	20.4	26.5	34.65	21.9	27.5	38.2			

Spatial and seasonal variation of MSW temperature in the reactor during the monitoring period (over 270 days) is presented in figures (9) and (10).

When microbes degrade MSW, they release heat, so an increase in the rate of degradation will also increase the rate of heat generation [28], higher temperatures thus indicate improved biodegradation. During the experiment, it was found that the temperature in the peak rainy season was in the range of 18.4 and 37.2 C° and variation was in the range of 22.9 and 43.1 C during the non- rainy season. The observed average temperature of 30.7 C in the MSW layer was within the optimum range for the effective microbial activity. The activity would be ineffective within or beyond the optimum range. The raise in temperature during the summer season enhances the microbial activity which also accelerates the biodegradation rate of MSW. Table (2) provides the statistical information regarding the MSW temperature regime.

Figure (10) and Table (2) depict the seasonal variation of temperature recorded from the two thermocouples placed in the CL of the bottom system. Observations from the Figure (10) show that the thermal response of the CL in bottom system varied in the range of 19.6 C during peak rainy season, to 41.3 C during non-rainy season.

4. Conclusions

In this paper, the behavior of the conventional landfill system is analyzed in laboratory conditions using a large-scale anaerobic reactor. The reactor consists of a system of bottom liners, MSW and top cover. The reactor was simulated with the measured amount of rainfall and monitored for leachate generation, moisture content, and temperature. The paper presents the results and observations obtained from the monitoring program from the first 270 days (August 2018 to May 2019). From the results achieved, the following conclusions can be drawn:

1. The leachate samples are analyzed for its physiochemical characteristics. Obtained values of pH in the range of 5.8 -7.9 indicate acceleration of biodegradation activity in the MSW. Total dissolved solids (TDS) reduced from 12,500 to 3,200 mg/L with increasing time. The observed reduction in EC from 17.6 to 6.2 indicates the solubility of salts in leachate. Reduction in COD from 2300 to 670 mg/L indicated onset of anaerobic condition.
2. The average volumetric moisture content of 53.03% and temperature of 30.7 C observed in the MSW indicate the achievement of optimal conditions for the process of microbial activity and degradation. During the monitoring period, the moisture content in the liner system attained its field capacity. In the cover system, the measured maximum temperature was 41.3 C.

References

[1] Modin., H, "Modern landfill leachates – quality and treatment", Ph.D. dissertation, Lund university, 2012.

[2] Chian, E., and Dewalle, F. "Sanitary Landfill Leachates and their Treatment", Journal of the Environmental Engineering DivisionAsce, 103(4), pp. 744-745, 1977.

[3] Gawande, N. A., Reinhart, D. R., Thomas, P. A., Mc Creanor, P. T., and Townsend, T. G. "Municipal solid waste in situ moisture content measurement using an electrical resistance sensor". Waste Management, 23(7),PP.667-674, 2003.

[4] Strous M, Van Gerven E, Zheng P, Kuenen JG, Jetten MS."Ammonium removal from concentrated waste streams with the anaerobic ammonium oxidation (anammox) process in different reactor configurations. Water Res 31(8):1955–1962, 1997.

[5] Yesiller N, Hanson JL, "Analysis of temperatures at a municipal solid waste landfill". In: Proceedings of the ninth international waste management and landfill symposium, Sardinia, Cagliari, Italy, 2003.

[6] Doll P. "Desiccation of mineral liners below landfills with heat generation". J Geotech Geoenviron Eng 123(11):1001–1009. 1997.

[7] Rowe., R.K . "Long-term performance of contaminant barrier systems". Geotechnique 55(9):631–678, 2005.

[8] Bouazza A, Nahlawi H, Aylward M. "In situ temperature monitoring in an organic-waste landfill cell". J Geotech Geoenviron Eng 137(12):1286–1289, 2001.

[9] Yes¸iller N, Hanson JL, Oettle NK, Liu WL, "Thermal analysis of cover systems in municipal solid waste landfills". J Geotech Geoenviron Eng 134(11):1655–1664, 2008.

[10] Rowe RK, Islam MZ, Hsuan YG , "Leachate chemical composition effects on OIT depletion in an HDPE geomembrane". Geosynth Int 15(2):136–151, 2008.

[11] Rowe RK, Islam MZ. "Impact of landfill liner time-temperature history on the service life of HDPE, geomembranes". Waste Manag 29(10):2689–2699, 2009.

[12] Koerner GR, Koerner RM. "Long-term temperature monitoring of geomembranes at dry and wet landfills". Geotext Geomembr 24(1):72–77, 2006.

[13] MoEF . "Municipal wastes (management & handling) rules1999-the gazette of India extraordinary", PART II-section 3-subsection (ii), Ministry of Environment and Forests, Government of India, New Delhi, India. 1999.

[14] Aljaradin M. and Persson K.M. "Numerical evaluation of different landfill daily cover in semiarid areas – Jordan", Int. J. Environment and Waste Management, 16(2), 95–110, 2015. .

[15] Bilgili, M. S., Demir, A., and Özkaya, B, "Influence of leachate recirculation on aerobic and anaerobic decomposition of solid wastes",Journal of hazardous materials, 143(1-2), pp.177-183, 2007.

[16] El-Fadel, M., Bou-Zeid, E., Chahine, W., and Alayli, B. "Temporal variation of leachate quality from pre-sorted and baled municipal solid waste with high organic and moisture content", Waste management, 22(3), PP.269-28, 2002. . .

[17] Bozkurt, S., Moreno, L., and Neretnieks, I. "Long-term fate of organics in waste deposits and its effect on metal release", Science of the Total Environment, 228(2-3), pp.135-152, 1999.

[18] Kjeldsen, P., Barlaz, M. A., Rooker, A. P., Baun, A., Ledin, A., and Christensen, T. H. "Present and long-term composition of MSW landfill leachate: a review", Critical reviews in environmental science and technology, 32(4), pp.297-336. 2002.

[19] Tränkler, J., Visvanathan, C., Kuruparan, P., and Tubtimthai, O. "Influence of tropical seasonal variations on landfill leachate characteristics—Results from lysimeter studies", Waste Management, 25(10), pp. 1013-1020, 2005.

[20] Rout, C., and Sharma, A. "Municipal solid waste stabilisation by leachate recirculation: A case study of Ambala City", International journal of environmental sciences, 1(4), pp. 645-655, 2010.

[21] Kylefors K, Lagerkvist A "Changes of leachate quality with degradation phases and time". In: Sardinia 97, proceedings of the sixth international landfill symposium, Sardinia, Cagliari, Italy, 1997.

[22] He, R., Wei, X. M., Chen, M., Su, Y., and Tian, B. H.. "Effects of concentrated leachate injection modes on stabilization of landfilled waste"., Environmental Science and Pollution Research, 23(4), pp. 3333-3341, 2016.

[23] Knox, K., and Jones, P. H. "Complexation characteristics of sanitary landfill leachates"., Water Research, 13(9), PP. 839-846, 1979.

[24] Fei, X., and Zekkos, D. "Factors influencing long-term settlement of municipal solid waste in laboratory bioreactor landfill simulators", Journal of Hazardous, Toxic, and Radioactive Waste, 17(4), pp. 259-271, 2012.

[25] Krug, M. N., and Ham, R. K. "Analysis of long-term leachate characteristics in Wisconsin landfills" (No. CONF-950978-). University. of Wisconsin, Madison, WI (United States), 1995.

[26] Monteiro, V. E. D., Melo, M. C., and Jucá, J. F. T. "Biological degradation analysis in Muribeca solid waste landfill associated with local climate", Recife, Brazil, In Proceedings of the Fourth International Congress on Environmental Geotechnics, Vol. 2, pp. 799-803, 2002.

[27] Bareither, C. A., Breitmeyer, R. J., Benson, C. H., Barlaz, M. A., and Edil, T. B.. "Deer track bioreactor experiment: Field-scale evaluation of municipal solid waste bioreactor performance", Journal of Geotechnical and Geoenvironmental Engineering, 138(6), pp. 658-670, 2011.

[28] Shearer, B. D. "Enhanced biodegradation in landfills (Doctoral dissertation, Virginia Tech). 2001.