LYSIMETER STUDIES ON LEACHATE GENERATION - STATE OF ART

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Abstract: Increase in population, industrialization and urbanization has led to the generation of thousands of tons of Municipal Solid Waste (MSW) daily. The disposal of solid waste by open dumping or in landfill is the most common practice in developing countries. Main problem by this activity is generation of leachate and if not properly managed results in various environmental problems. Lysimeters have been widely applied to simulate landfills in the study of leachate generation. In this paper an attempt has been made to take stock of working of lysimeter and work carried out by researchers across the globe. A case study to investigate the effect of age of MSW on leachate contents has been attempted. Age of MSW is found to play an important role in affecting leachate concentration. The concentrations of various contents of leachate except pH were increased with the passing of time till the 30 days, and then decreases in last 10 days. However decrease in leachate pH with time has been observed, and is attributed to formation of fatty acids due to degradation of carbohydrates.

IndexTerms: MSW, Landfill, Lysimeter, Leachate characteristics.

I. INTRODUCTION

Increasing population levels, rise in economic growth and living standards across the globe, especially in India has accelerated the generation of Municipal Solid Waste (MSW). Thus the management of the MSW has become a considerable issue along with the other environmental problems especially in densely populated cities in developing countries. Out of the different disposal methods of solid waste, landfill is the oldest and easiest method. Physical, chemical and biological processes occur inside the landfill site which results in production of leachate and land fill gas (Didarul et al. 2013). Landfill leachate contains high concentrations of organic matter, nutrients, pathogens and heavy metals, which if it is not treated properly, it causes pollution of ground water sources (Rout 2010; Abdoli et al. 2012.). However the several factors like age of landfill, waste composition, depth of the waste, moisture availability, temperature, climatic variation, geological characteristics, volume of water running through landfill influence the degradation process inside the landfill and thereby the quality of leachate produced (Qdais 2008; Yeva 2009; El-Fadel 2002). But most of the landfill in developing countries does not have any liners at the base or proper top covers because of which large quantity of leachate generated percolates through the ground and pollutes the ground water (Rafizul and Alamgir 2012). Therefore the need of the day is to quantify and characterize the leachate generated from the MSW landfill sites and to suggest the treatment options, so that the pollution of subsurface water is prevented.

II. LYSIMETER

The word lysimeter is a combination of two Greek words “Lusis” which means “Solution” and “metron” which means “Measure”. Lysimeter is a simulated form of sanitary landfill in the sense of control device (Ahsan et al. 2014). Lysimeter have been widely applied to simulate landfills in the study of leachate generation. Investigators prefer lysimeter because of its easier control conditions and make measurement of the leaching process easier compared to full scale landfill. It is also less expensive, simple in installation and operation (Farquhar 1988). A lysimeter usually involves a drainage layer at the bottom (Rafizul et al. 2011), a geotextile sheets to prevent rapid clogging of a pipe and a tap to collect the leachate. Above this solid wastes are filled with certain compaction. Lysimeters can be aerobic or anaerobic in operation. In a study made by Stessel and Murphy (1992), it was observed that degradation was enhanced by aerobic degradation method compared to anaerobic operation. Various authors carried out laboratory studies using lysimeter made up of different materials like PVC, stainless steel, brick walls and of varied dimensions as listed below in the table. Table 1 depicts the studies carried out by researchers.

Table 1: Materials and Dimensions Used for Construction of Lysimeter

Author	Materials used for Construction	Dimensions	
		Dia,mm	Height,mm
Karnchanawong and Yongpisalpop (2009) , Qdais and Alsheraideh (2008), Didarul et al.(2013)	PVC	150-200	1000-3000
Aljaradin and Persson (2016), Stessel and Murphy(1992), Alfred (2013)	Stainless steel/ Corrugated Galvanized Steel/Steel	460-570	870-2400
Visvanatathan et al.(2003), Kasam et al.(2016)	Concrete Rings Plastered with Ferro Cement/ Concrete	700-1400	2400-3500
Rafizul et al.(2011)	Brick Wall	1480	3350

III. WORKING OF LYSIMETER

Three distinct steps are involved in working of lysimeter and are discussed below

3.1 Loading of MSW

As mentioned above the lysimeter simulates the actual landfill conditions, and hence the MSW is to be placed in the lysimeter simulating the composition of MSW of study area considered which varies from place to place. To make the degradation of the waste easier and faster, it is better to cut all the categories of MSW to small pieces to less than 2cm before loading into lysimeter.

3.2 Simulation of Actual Field Density

Along with loading of lysimeter simulating the actual composition of MSW of study area, it is also very much essential to correlate with the actual field density. The mass of the various contents of MSW that should be introduced to lysimeter of known volume simulating the actual field density of MSW landfill site is presented by Aish et al. (2014).

3.3 Water Addition

To simulate the actual infiltration through the landfill, water is to be added to the MSW, filled in the lysimeter. The rate of water addition depends on several factors like rate of precipitation, type of materials used as cover material, presence of landfill cover and evapotranspiration and losses due to runoff (Armstrong and Rowe 1999). The researchers across the globe suggested formulae / thumb rule to calculate the quantity of water to be added. Some of these are discussed below.

3.3.1. Equation proposed by Tchobanoglous and Kreith (2002)

The equation proposed by the authors as quoted by Aish et al. (2014) is as follows.

Water to be added $$W(litres) = LXA \quad (1)$$

Where $A(m^2)$ = Surface area of Lysimeter
$L(mm)$ = Depth of leachate water and can be calculated by using the equation given below :

$$L = P(1-C) - E \quad (2)$$

Where $P(mm)$ = Total precipitation in a season
C = Leachate coefficient in the study area which is a function of average daily precipitation and can be calculated by the relationship given by Jaber and Nassar (2007)
$E(mm)$ = Evaporation

However Aish et al. (2014) has documented the specimen calculation, based on precipitation and evaporation during winter and summer season, leachate coefficient and surface areas of Lysimeter.

3.3.2 Equation proposed by Sanphoti et al. (2006)

Water to be added (litres/day) = {(mean rainfall in each month/mean rainy day)A}0.5 (3)

Where A(m^2) = Surface area of Lysimeter and

0.5 is the quantity of rainfall percolating through the landfill at 50% of the total precipitation.

However the authors have presented the specimen calculations for summer and winter seasons.

IV. CHARACTERISTICS OF LEACHATE

When rainwater percolates through MSW landfill, it dissolves salt, pickup organic constituents and leaches heavy metals. The uptake may be from both physical attractions, hydrostatic and fermentative process. However the leachate characteristics will vary depending on composition of MSW, age of landfill, precipitation, humidity, temperature, compaction, height of landfill, cover materials used, leachate recirculation etc.

The characteristics of leachate documented widely by various researchers across the globe could be found in literature elsewhere. Further the top cover design is one of the primary parameter which affects leachate generation (Visvanathan et al. 2003). Open dump simulated lysimeters with no cover soil produces more quantity of leachate compared to lysimeter with soil covers. For example, sanitary landfill operational mode with clay soil as a bottom cover generated minimum quantity of leachate of all the sanitary simulated lysimeters. Characteristics of leachate, with different soil covers and number of days of operation as presented by researchers are depicted in table 2.

Table 2 :Effect of Soil cover on Leachate Characteristics

Author Reference	Soil Cover	No of days of operation	Leachate Characteristics
Rafizul et al(2012)	L1- Top cover (compost 150mm) Bottom Clay– 400mm depth L2- Top cover(Stone chips and coarse sand each 100mm thickness and 300mm Clay layer and 600mm top soil No bottom liner L3- Top cover (natural top soil - 900mm depth)	1000days	COD* (mg/l) - L3> L2>L1 BOD*(mg/l) - L1>L3>L2 NH_4-N*(mg/l) - L2>L3>L1 Chloride(mg/l) - L1>L3>L2 Hardness(mg/l) as $CaCO_3$ - L2>L3>L1
Karnchanawong and Yongpisalpop (2009)	Only Top Cover L1- Sandy loam soil (Sand silt: clay =72:22:6) L2-Silty loam soil with (sand:silt:clay=38:54:8). L3-Clay soil (Sand: Silt:clay) 18:30:52) L4- No Top Cover Only Solid Waste	180days	COD*(mg/l) -L3>L2>L1>L4 BOD*(mg/l) - L2>L3>L1>L4 NH_3-N*(mg/l) - L1>L4>L1>L3 EC*(ms/mhos)-L3>L4>L2=L1
Didarul et al (2013)	L1-Without Top cover Bottom- 300mm gravel L2-Top cover (Sand: silt: clay= 68:19:13) Bottom Clay- 300mm depth. L3-Top cover (sand: silt: clay=56:27:17) Bottom - coarse sand 200mm gravel 100mm L4-Same as L2 but presorted MSW is used	160days	COD*(mg/l) - L1 >L4>L3>L2 BOD*(mg/l) - L1>L3>L2>L4 Hardness(mg/l) as $CaCO_3$- L3>L2>L4>L1 Sulphate(mg/l)-L1>L3>L2>L1 Chloride(mg/l)-L3>L2>L1>L4

Also the age of the leachate plays an important role in affecting the leachate composition. The investigators reported the higher concentration of biodegradable organic matters in the leachate at the early ages of landfill. Further lower concentrations biodegradable organic matters and highly concentrated nitrogenous compounds in leachate with increase in landfill age up to a certain time and then decrease in concentrations have been reported (Renou et al. 2008; Al Sabahi et al. 2009). Such a phenomenon is attributed to the reduction in organic contaminants with age. Leachate characteristics with age as quoted by Renou et al. (2008) are presented in table 3.

Table 3 : Leachate characteristics according to age of landfill (Renou et al. 2008)

Parameters	Young	Intermediate	Old
Age (years)	<5	5-10	>10
pH	6.5	6.5-7.5	>7.5
COD (mg/l)	>10,000	4000-10000	<4000
BOD_5/COD	>0.3	0.1-0.3	<0.1
Organic compounds	80% volatile fat acids	5-30% VFA + humic and fulvic acids	Humic and fulvic acids
Heavy metals	Low –medium	Low	Low
Biodegradability	High	Medium	Low

Enhanced waste decomposition and methane gas production with leachate recirculation has been reported by researchers (Rastogi et al. 2014; Bilgili et al. 2006; Kasam et al. 2013; Sanphoti et al. 2003; Hernandez- Barriel et al. 2014; Pohland et al. 1992; Rout and Sharma 2010; Cossu et al. 2003). Positive effect of recirculation on anaerobic degradation of solid waste than aerobic degradation has been demonstrated. Further decrease in the amount of leachate discharge in both aerobic and anaerobic landfills has been reported. Studies also revealed decrease in BOD, COD, Total Kjehldahl Nitrogen (TKN) and Volatile fatty acid (VFA) contents in leachate due to leachate recirculation.

Further lower pH and Oxidation Reduction Potential (ORP) in leachate with leachate recirculation has been observed. COD removals of 89.93% and 80.30% with leachate and without leachate recirculation are reported by investigators. Sanphoti et al. (2003) based on their studies using lysimeter, reported the effect of addition of water on stabilization. The studies revealed the attainment of stabilization phase at 180 days and 290 days with addition of water and without addition of water respectively. However studies also reported the problems associated like accumulation of volatile organic acids and ammonia with leachate recirculation.

V. CASE STUDY

Findings of experimentation carried out as a part of research work using lysimeter to evaluate the effect of age of MSW on characteristics of leachate are presented in this section.

5.1 Experimental Set up

In order to generate the leachate, a lysimeter was constructed to simulate the landfill site. Fig. 1 shows the line diagram of the lysimeter. The lysimeter consists of steel drum of 0.86m in height and 0.54m in diameter. At the bottom of the drum to support the solid waste, a steel stand with a steel mesh on it was placed. Below the stand, gravels are placed to provide good drainage system. A tap was provided at the bottom of the steel drum to collect the leachate generated.

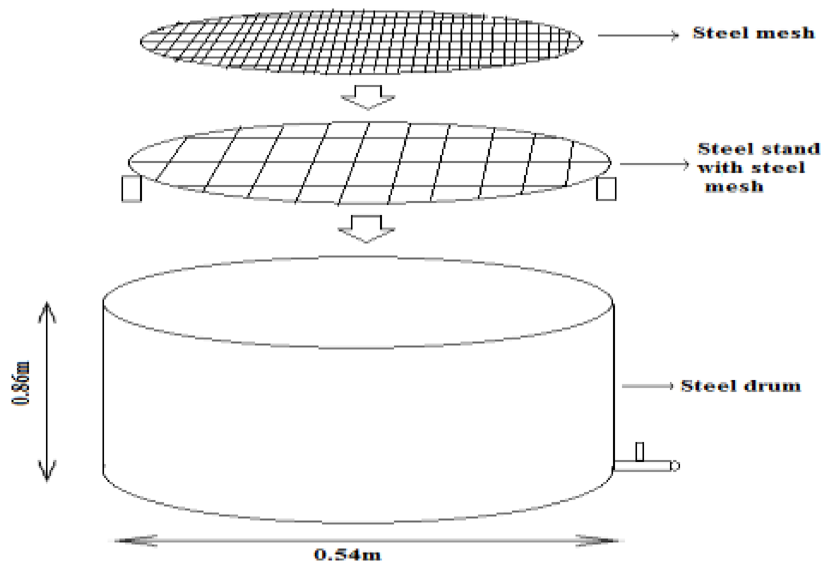

Fig. 1: Line Diagram of the Lysimeter

5.2 Solid Waste Compositions

20 Kg of grab samples from different pockets of study area (Davangere, Karnataka) covering residential, commercial and industrial areas on different days were collected. The contents of solid wastes were thoroughly mixed to homogenize it. Using quartering method, samples are drawn and were analysed for characteristics as per IS: 10158 (1982), IS: 9235(1979). The percentages of contents are shown in table 4.

Table 4 : Contents of Solid Waste of Study Area

Content	organic waste	paper	plastic	Metals	glass and crockery	ash brick fine earth	Rubber and leather	Textile	Others
% of contents	59	9	7	1	3	10	1	2	8
Kg by weight	26.74	4.08	3.17	0.45	1.36	4.53	0.45	0.9	3.63

5.3 Loading of Lysimeter with MSW

Procedure given by Aish et al. (2014) was employed for loading of MSW. Based on the volume of lysimeter ($0.166m^3$) and density of solid waste ($273kg/m^3$), weight of sample was calculated. Again the kg of various contents (Table 4) to be placed in lysimeter was calculated. All the categories were cut to small pieces, and were very well mixed manually and introduced into the column without compaction.

5.4 Water Addition

The amount of water to be added was calculated by using equation suggested by Aish et al. (2014). The total precipitation (June to October – monsoon season) was 717.95 mm total evaporation was 384.88 mm runoff coefficient was 0.1. The water to be added worked out to be 43.37 litres.

5.5 Characteristics of Leachate Generated

The leachate was analysed for its characteristics corresponding 10, 20, 30 and 40 days of age of solid waste composted in the lysimeter and are presented in table 5.

Table 5 : Characteristics of Leachate Generated using Lysimeter

Sl. No.	Parameters	Ranges corresponding to the age of the compost mentioned			
		10 days	20 days	30 days	40days
1.	pH	5.83	5.42	5.34	5.21
2.	COD (mg/l)	62000	65500	67000	63000
3.	Colour (Pt-Co)	7800	9250	15560	12290
4.	Hardness mg/l as $CaCO_3$	5200	8750	9200	8900
5.	EC (ms/cm)	8.15	8.66	8.72	8.32
6.	Chloride (mg/l)	2800	3720	4250	3850
7.	TDS (ppm.)	4630	4823	4840	4740

5.6 Results and Discussions

Based on the results tabulated in table 5, the following inferences are drawn.

- pH of the leachate decreases with time it may be attributes degradation of carbohydrate in the leachate to form fatty acids (Al-Muzaini et al. 1995).
- The results demonstrated that TDS and EC increased at the first 30 days, and then decrease is detected in the last 10 days. Further it is inferred that the effect of the dilution that could occurred by the continuous addition of water resulted in decreased concentration of the TDS after 30 days.
- The levels of COD were relatively high. Generally, young age leachate will be high in COD as a result of organic waste decomposition. This is similar to what demonstrated by (Al-Sabahi et al. 2009; Al-Yaqout and Hamoda 2003). COD increased with the passing of time till the 30 days. While during the last 10 days, the decrease in COD has been observed. The decrease in COD generally referred to the reduction in organic contaminants.
- Same trends have been recorded with chloride and hardness contents.

VI. CONCLUSIONS

Based on the review of papers on lysimeter and case study presented in this paper, the following conclusions have been drawn.

- Lysimeter can be used to generate the leachate from MSW under varied conditions of experimentation.
- The paper throws light on procedure to be followed for placement of MSW in lysimeter simulating actual field density water to be added.
- The paper also takes stock of factors affecting characteristics of leachate.
- Paper also documents the work carried out by researchers on lysimeter applications.
- Time plays (age of MSW) plays an important role in affecting leachate concentration.
- The concentration of the contaminants in the leachate generated generally increases with time up to a certain time, and then it decreases.

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