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RESEARCH ARTICLE

VARIATION OF LANDFILL LEACHATE CHARACTERISTICS-RESULTS FROM LYSIMETER STUDIED IN BANGLADESH

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ABSTRACT

This study aims to characterize leachate generated from municipal solid waste (MSW) deposited in landfill lysimeter constructed at KUET campus, Bangladesh. Four different situations of landfill were considered here. The leachate characteristics, leachate generation, settlement pattern had been continually monitored. The leachate generation had followed the rainfall pattern and the open dump lysimeter-A without top cover was recorded to have highest leachate generation. In the laboratory through standard methods leachate concentrations by the means of pH, llkalinity, turbidity, BOD, COD, sulfate, hardness, conductivity, total solids, salinity, total iron , copper, nickle, and zinc were measured and monitor. The heights and diameters of all lysimeters were 1.8m and 0.20m respectively. Result reveals that lysimeter operational mode had direct effect on leachate quality. Finally, it can be concluded that the knowledge of leachate quality will be useful in planning and providing remedial measures of proper liner system in sanitary landfill design and leachate treatment.

Keywords: Landfill operation, solid waste, open dump, sanitary landfill, cap and base liner leachate characteristics, Khulna.

INTRODUCTION

Solid waste generation is a growing global issue due to the large increase in solid waste production. This increase in waste quantity requires improving and expanding the solid waste management options [1]. Until recently, the environment was not an issue in a developing country like Bangladesh, and solid waste management was definitely not the prime concern of environmentalists and the government. It has only been in 1990s, when certain nongovernmental organizations (NGOs) started working and highlighting the pathetic state of municipal waste services provided in the country that the decision-makers realized the importance of this particular aspect of environmental management [2]. Landfill co-disposal is the most commonly used waste management method worldwide. Physical, chemical, and biological processes occur within a conventional landfill to pro-mote the anaerobic degradation of solid waste and result with the production of leachate and landfill gas for a very long time. Landfill is a unit operation for final disposal of 'municipal solid waste' (MSW) on land. This term encompasses the other terms such as 'secured landfill' and 'engineered landfills' which are also sometimes applied to MSW disposal units [3]. Open dump and sanitary landfill are two types of landfill practices all over the world. In South and South East Asia more than 90% of MSW is disposed of in open dumps [4]. In open dumping disposed waste are neither compacted nor covers with soil. Thus the open dump site characteristics are unplanned heaps of uncover waste, burning waste at the dump site, pools of standing polluted water, rat and fly infestation and waste scavenging at dump site [5].

The open dump approach still remains the predominant waste disposal alternative in developing countries erectionting noteworthy nuisance and environmental problems. Sanitary landfill is a land disposal site employing an engineered method of disposing of solid waste on land in a manner that minimize volume, and applying and compaction cover material at the end of each day [6]. Lysimeter is a simulated from of sanitary landfill in the sense of control device. The word lysimeter is a combination of two Greek words "Lusis" means "Solution" and "Metron" means "Measure" [7]. So lysimeter means leachate quantity measure and leachate problem solution. Leachate is the most tainted liquid originated in a landfill due to the water content that enters the landfill from external sources like surface drainage, rainfall, groundwater, and water from waste material. The leachate generated from MSW disposal sites is considered as one of the highly contaminated resources from physical, chemical and biological point of view. However, the best possible knowledge of leachate characteristics at a specific site is an essential management tool [8]. This is not only important for new contaminated needs designed in advance, where leachate will be extracted, but also important for the old landfill where the environmental safeguards rely on the natural attenuating properties of the geological strata, to reduce the level of contaminant to environment [9]. Sanitary landfill leachate is the most complicated and costly wastewater to treat due to its high content of organic and inorganic pollutants [1]. As a result proper treatment of leachate is almost impossible in developing countries like Bangladesh due to cost effect. Therefore it is necessary to develop strategies to reduce pollutants concentration from leachate. The top cover used in the sanitary landfill operation might be considered as an option to decrease the pollutants' concentrations in the leachate [10]. Hence, the study will allow having an outcome for low cost solid waste disposal technology and that will be sustainable also, on the basis of effects of soil cover type on characteristics of leachate generated from landfill lysimeter.

MATERIALS AND METHODS

The detailed procedure for the design and set up of four pilot scale landfill lysimeter at KUET campus, characterization of MSW and soil deposited in each lysimeter as well as the analytical methods of leachate were presented and hence discussed in the following articles.

Set-up of Landfill Lysimeter: Four lysimeter made of PVC pipe were prepared in this study. Among four, one lysimeter simulated as open dump i.e. filled solely with MSW having no top cover soil and 300mm Gravel in the bottom designed as lysimeter-A. In this lysimeter the MSW was not covered by a top cover system to pervert the movement of air, water and generated landfill gas (LFG). Moreover, the thickness of the deposited MSW in lysimeter-A is such that it is expected the atmospheric air can move in the entire MSW deposited in this cell with negligible inference. Due to the mentioned practical situations, lysimeter-A, represents the aerobic condition.

In contrary, the other three lysimeters were treated as sanitary landfill having three different types of soil covers and hence designated lysimeter-B, lysimeter-C and lysimeter-D. These three landfill lysimeter operated as an anaerobic conditions in presence of cover soil. The cross section of reference cell with in detailed for sample lysimeter shown in Figure 1. The height and inner diameter of all lysimeter were 1800 mm and 200 mm, respectively. The upper 100 mm free space is for adding rainfall. The lower part containing a gravel layer served as the waste base and allowed the leachate to flow through the collecting pipe. A geo-textile sheet was used to avoid rapid clogging of the under laying pipe. The operational conditions of all the concerned lysimters were presented in Table 1.

Table 1: Operational conditions used in lysimeter to simulate different landfill conditions

Lysimeter	*Operating condition*	*Refuse (kg)*	*Liner specification*		*Waste Type*
			Top	*Bottom*	
A	Open dump	22	-	300mm Gravel	MSW
B	Sanitary landfill		Soil Type-1	300mm CCL	
C			Soil Type-2	200mm coarse sand+ 100mm gravel	Presorted MSW
D					

Characterization of MSW Deposited in Landfill Lysimeter: The quantity and degree of contamination of leachate depends on physical and chemical characteristics of MSW, rate of degradation of organic fraction from MSW, degree of compaction, height of waste and therefore age of MSW in deposited landfill [11]. To this attempt, before filling the MSW, the MSW was characterized according to their physical and chemical composition and hence described as follows.

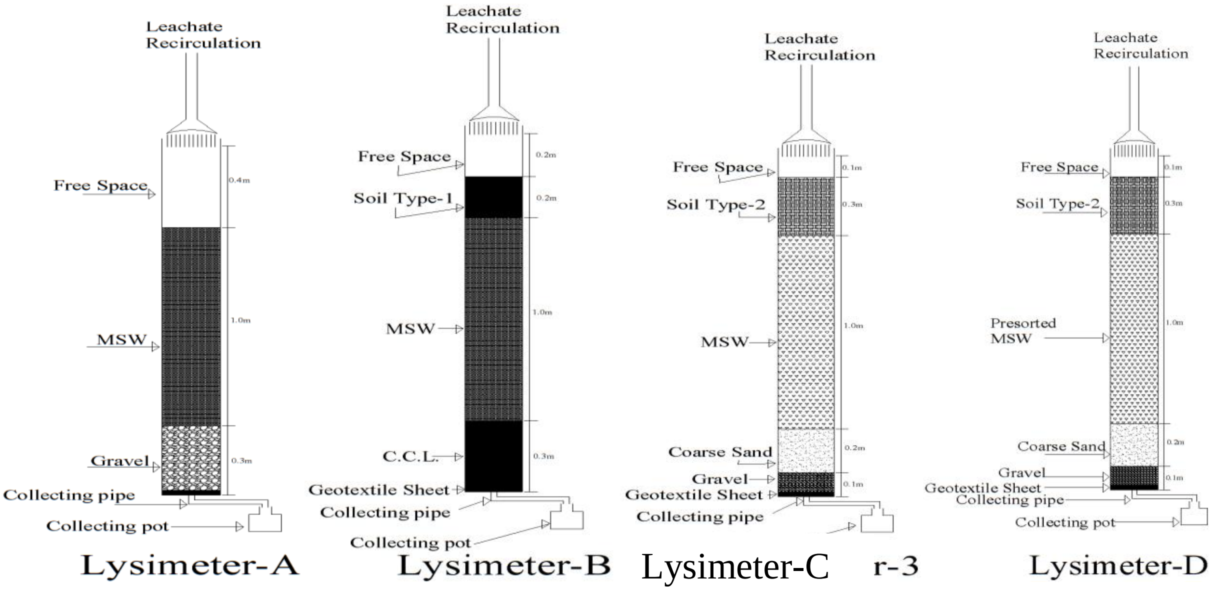


Figure 1 Experimental lysimeter A, B, C and D at KUET campus

Soil Type-1: Sand: Silt: Clay=68: 19: 13, Sp. Gravity=2.69; Soil Type-2: Sand: Silt: Clay=56:27:17, Sp.Gravity=2.7, Gravel: Size: 5~19 mm; FM=2.39, coarse sand: FM=2.62.

Table 2: Sieve analysis of MSW deposited in landfill lysimeter in percentage finer

200 mm	100 mm	76.2 mm	38.2 mm	19.1 mm	9.52 mm	4.76 mm
100	95.44	85.04	42.73	11.11	3.89	0

Physical Characterization: 7 Kg of MSW was taken and hence sorting all the composition consists of 63.64(w/w) of food/vegetable, 13.34 (w/w) of paper and paper products, 1.76 (w/w) of plastic and polythene, 14.99 (w/w) of textile and wood, 3.16(w/w) of glass etc. Here, the predominant component is food and vegetables waste having high organic content on which quality of leachate primarily depends on. Moreover, the organic content, moisture content, volatile solids (VS) and ash residue of MSW were 42 %, 31 %, 58 % and 11%, respectively. The moisture content of MSW was measured in the laboratory by incinerated in the electric oven at 105^{o}C for 24hr. Moreover, for determining the organic content MSW was incinerated in the muffle furnace at 550^{o}C for 5 hr. The detailed procedure for measuring the moisture and organic content of MSW in lysimeter can be obtained in Austrian Standard [12], volatile solid by ignited MSW at 550^{0}C, after burning the MSW ash residue was found. All the findings of MSW are agreed with a feasibility study conducted on characteristics of MSW by [13] in Khulna city, Bangladesh.

Grain Size Analysis: Before filling the landfill lysimeter with MSW, analysis of finer fraction was done and is in Table 2. The constituents of particle size of MSW were determined with the use of a set of locally manufactured sieves of opening sizes are 300, 200, 100, 76.2, 38.2, 19.1, 9.52, 4.76 and 2.38mm considered as standard size [14]. Here, it is important to note that the percent finer of MSW was 100% in 200 mm sieve openings as well as gradually decreases for smaller sieve openings (Table 2). The findings are agreed well with the percent finer of MSW in six major cities, especially in Khulna city, Bangladesh in a feasibility study conducted by [13].

Leachate Sampling and Analysis: Bangladesh is a country of six seasons. But in this study covers summer season and winter season, but also the rainy season was considered by adding extra water after 130 days. After achieving all leachate, leachate was recirculated in each lysimeter. The study was conducted for 6-month period. Leachate quantity, waste settlement rate and leachate characteristics i.e. pH, electric conductivity (EC), hardness, total solids (TS), sulfate (So_4^{2-}), chloride (Cl^-), alkalinity as

$CaCO_3$, COD, BOD_5, iron (Fe), chromium (Cr), copper (Cu), nickle (Ni) and Zinc (Zn) were determined in approximate ten days interval.

Analytical Methods for the Appraisal of Leachate

In the laboratory, pH was determined by pH meter (HACH, Model No. Sens ion 156), EC by conductivity meter (HACH, Model No. Sens ion 5), chloride by potentiometric titration method using silver nitrate solution, alkalinity by titration method, COD by closed reflexive method as per the standard methods [15] as well as BOD_5 by dilution method (titration). In addition, TS dried at 103-105 ^{0}C and sulfate by Sulfa Ver 4 method. Moreover, heavy metals viz., Cu, Cr, Ni, Fe and Zn were analyzed using spectrophotometer (HACH; DR/2400) as per the standard methods [15].

RESULTS AND DISCUSSIONS

Leachate Generation: Leachate is formed in solid waste landfill when the refuse moisture content exceeds its field capacity (rainfall, initial moisture content, etc.) [11]. Factors affecting the leachate generation from landfill are solid waste composition, initial moisture content, rainfall, evaporation and infiltration rate of rainfall and therefore the climatic condition under which the landfill is situated [8]. Amount of rainfall added and leachate generated from different concerned lysimeter are summarized in Figure 2 over time. After 60 days generation is become slower and cumulative amount of leachate generated from lysimeter A, B, C and D were 1.51, 1.13, 1.24 and 1.19 L, respectively. Form the next 60 days, the leachate amounts generated in a low amount. Then about 2.5 L added to each lysimeter, due to the top cover that can reduce the percolating of rainwater [8]. Consequently, the lysimeter having top cover can lessen the leachate quantities around 29 %, compared with the lysimeter using no cover soil. Cumulative amounts of leachate from lysimeters having cover soils showed no any significant difference among them. A study conducted by [16] suggested that lysimeter having no cover generated the highest amount of leachate and lysimeter having sandy loam soil as cover soil generated the lowest. Again [8] shows that open dump lysimeter produced the utmost amount of leachate in contrast to sanitary landfill lysimeter. So the findings are convincing according to [16] and also in [8]. It can be decided that, sanitary lanfill operational mode with a clay soil as a bottom cover is proved to be most efficient in reduction of leachate quantity.

ettlement of MSW **in Landfill Lysimeter:** Waste settlement in MSW landfill is the most significant problem, among all the difficulties of utilizing landfill sites for future development. The settlement mechanism in landfill is complex enough. The variation of waste composition and biological activities causes the landfill settlement in a non uniform pattern. The settlement rate of MSW deposited in lysimeters during the experimental period is summarized in Figure 3. At beginner excessive settlement occurred in the lysimeter having presorted MSW. The ultimate settlement amount in different lysimeters was 38.4, 25.5, 30 and 35.5% (% of waste thickness) for lysimeter A, B, C and D, respectively. The highest amount of settlement occurred in lysimeter "A" as the highest amount of leachate was produced from it. Here it is fascinating to note that though the highest amount of settlement occurred in lysimeter "A" the initial settlement rate were found higher for lysimeters having cover soils. As the top cover about 20 kg soil was used at the top of the waste in those lysimeters. Due to the additional weight of the soil on the waste, the waste height was compacted at the initial stage and initially settlement rate was found higher for the lysimeter having top cover. But at the latter stage waste settlement rate was increased in lysimeter "A". A study conducted by [17] and [18] reported that a cell with highest compaction density had the lowest settlement. **[19]** stated that rate of settlement of MSW in landfill depends primarily on the compaction of refuse, moisture content response for biodegdrdation of MSW in landfill, percolation of rainwater in refuse and the operational practices of landfill. As no significant compaction was occurred in the time of dumping lysimeter so at the latter stage, waste in lysimeter settled more and produced highest amount of leachate. In accordance with [17], [18]and [19] the findings are valid.

Leachate Characteristics: The concentrations and load of leachate pollutants, generated from MSW deposited in landfill lysimeter at varying operational condition presents in Table 3 hence discussed in followings.

pH: pH is basically the buffering capacity of the CO_3-HCO_3 system in water. pH is considered as the most significant parameter that affects most of the pollutants concentration in leachate [1]. pH in leachate <7.0 is in the acidic range and pH >7.0 is in alkaline range [20]. Table 3 exhibits that average value of pH of lysimeter-A is the highest and is in alkaline range and pH of the sanitary lysimeter-B, lysimeter-C and lysimeter-D is in basic range. A study by [1] found that pH values were higher in open dump landfill reactor compared to sanitary landfill reactor. So, the findings of this study are well agreed with [1]. Discrepancy of pH between the lysimeters occurred due to open dump and closed dump condition.

Table 3: Concentrations of leachate generated from MSW in landfill lysimeter

Parameter	Lysimeter-A	Lysimeter-B	Lysimeter-C	Lysimeter-D
pH	7.52–8.63 (8.02)	6.77-7.92 (7.38)	6.52-8.54 (7.36)	7.04-8.31(7.57)
EC	4.75-9.45(7.05)	3.51-6.02(4.80)	7.6-13.98(9.42)	6.66-11.28(9.13)
So_4^{2-}	600–1820 (1343)	620-1855 (1168)	695–1890 (1209)	755–2060 (1101)
Cl^-	700 – 3830 (1972)	610–3745 (1988)	565–5175 (2143)	510–3525 (1865)
TS	6587-19250(9922)	5149-14000(7812)	12387-19750(15834)	1123-20750(14458)
Alk.	2400-3900(3523)	750-4650(2695)	1500-7760(4821)	1500-11100(4850)
COD	3165-39725(17063)	2580-34460(14492)	2350-36505(15453)	2065-32305(13436)
BOD_5	650-21465(9520)	1025-18995(8247)	1635-20460(9403)	850-17420(7711)
Fe	0.5–20.2 (3.47)	1.2–7.4 (4.06)	1.5–7.6 (3.89)	1.7–7.2 (5.41)
Cr	0–0.73 (0.385)	0–0.56 (0.28)	0–0.6 (0.3)	0–0.5 (0.25)
Cu	0–0.78 (0.174)	0–0.51 (0.121)	0–0.58 (0.126)	0.001–0.42 (0.113)
Ni	0–0.41 (0.100)	0–0.38 (0.091)	0–0.56 (0.095)	0–0.45 (0.087)
Zn	0–2.4 (1.16)	0.2–1.64 (0.97)	0.2–1.69 (1.05)	0–1.51 (0.84)
Hardness	1639-18474(4512)	3334-19527(6434)	2500-14029(8757)	1234-11945(5274)
Turbidity	156-720(388)	3.3-535(123)	126-688(325)	1.68-630(463)

Note: EC=Electric Conductivity; So_4^{2-}=Sulfate; Cl^-=Chloride; TS=Total Solid;TKN= Total Kjeldahl Nitrogen Fe=Iron; Cr=Chromium; Cu=Copper; Ni=Nickel; Zn=Zinc. pH has no unit; conductivity is in mS/cm; rests are in mg/L; Alk.=Alkalinity. Range is given for the minimum and maximum values, while the value of parenthesis indicates the mean values.

Moreover, mean value of pH is the highest for lysimeter-A and lowest for lysimeter-B. A similar study conducted by [16] stated that average value of pH is the maximum in lysimeter having no cover soil and minimum in lysimeter having clay soil as cap liner. Figure 4 illustrates that for all lysimeters pH was sharply increasing in nature for first 50 days from 7.54 – 8.24, 7.56 - 7.92, 7.55 – 8.06 and 7.58-8.21 for lysimeter-A, B, C and D, respectively. Then sharply decreased up to 80 days from 8.24– 7.52, 7.92- 6.77, 8.06 - 6.66 and 8.21 - 7.04 for lysimeter-A, B, C and D, respectively. However, pH rises up when the microorganisms utilize the carbonates in the water and drops down while the decompositon of organic pollutants occures. At 90th days pH increased again for all types of lysimeter and at last stage pH was leisurely declining in nature and got a more or less unwavering state.

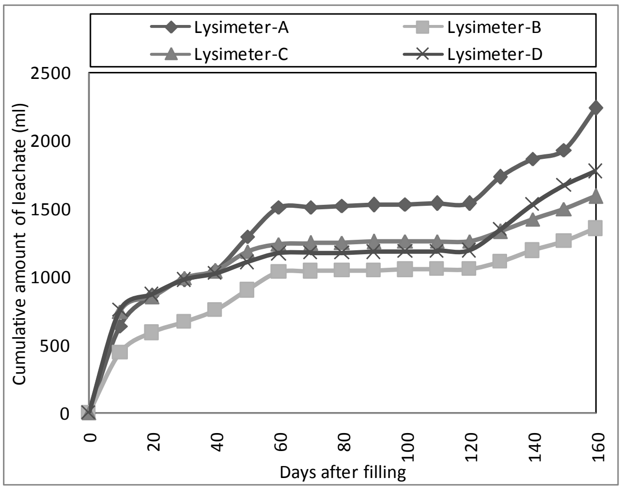


Figure 2 Cumulative amount of leachate generation in landfill lysimeter at varying operational condition.

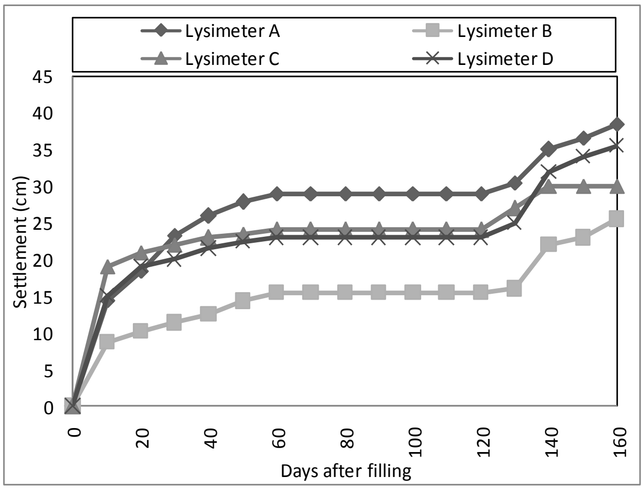


Figure 3 Variation of Settlement of MSW in landfill lysimeter at varying operational condition.

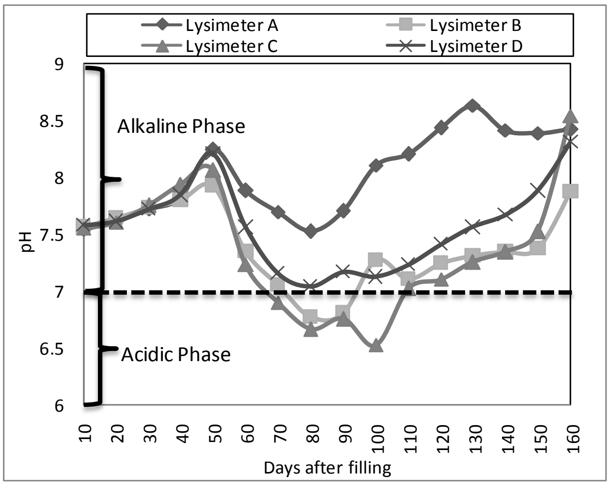


Figure 4 Variation of pH in landfill lysimeter at varying operational condition.

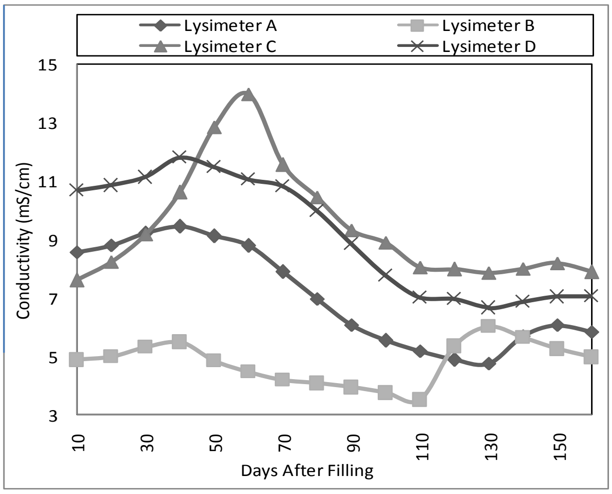
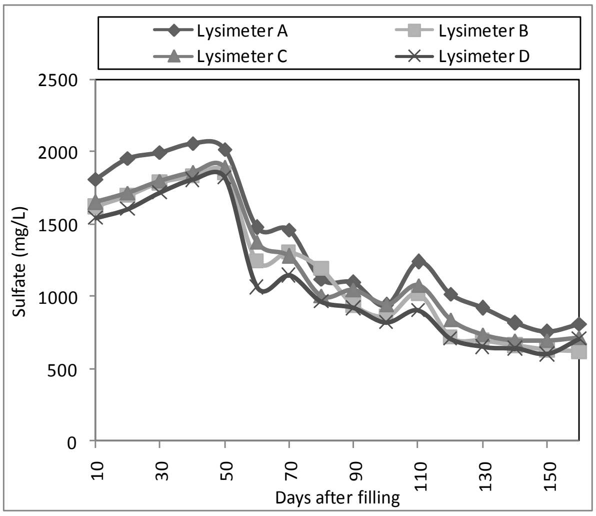


Figure 5 Variation of conductivity in landfill lysimeter at varying operational condition.



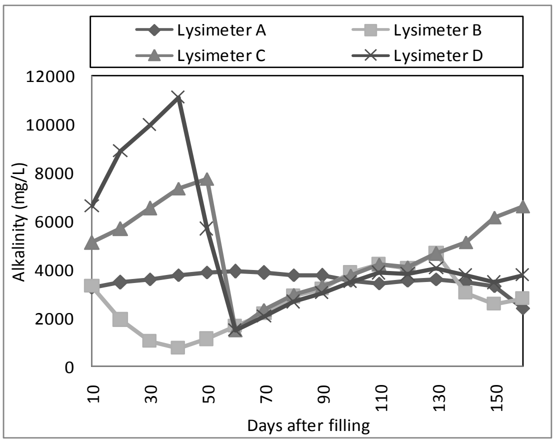


Figure 8 Variation of alkalinity in landfill lysimeterat varying operational condition

Figure 6 Variation of sulfate in landfill lysimeter at varying operational condition

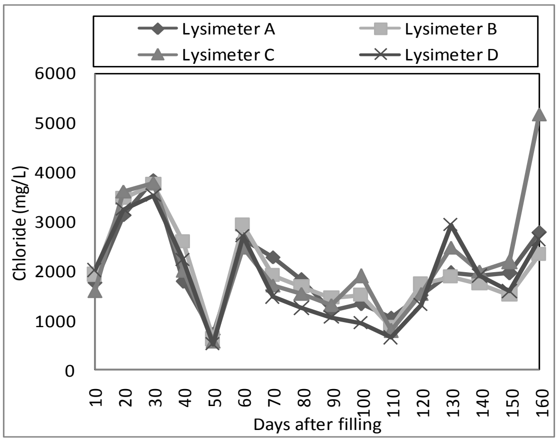


Figure 7 Variation of chloride in landfill lysimeter at varying operational condition

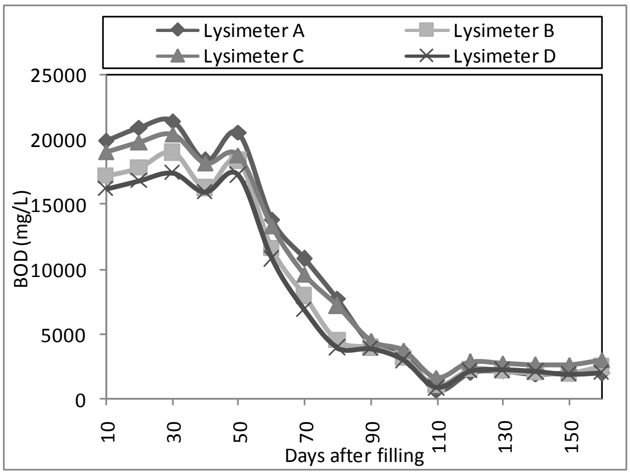


Figure 9 Variation of BOD in landfill lysimeterat varying operational condition

Conductivity : The salts content in leachate is harmony to the electric conductivity (EC) values and it reflects its total concentration of ionic solutes and is a measure of the solution's ability to convey an electric current [8]. From Figure 5 we see that every lysimeter shows different character but we make some general comments on it, i.e; after dumping few days(40-60) conducvity was increased slightly after then it decrease upto 110-130th days after it shows a wave nature. That means conductivity increase with the increase of pH and decrease with the decrease of pH . So it's a different case for pH and conductivity. It may cause for using the different types of top and bottom layer as well as sorting of waste.The findings and relationship are different from [8]. From the Table 3, average value of EC is the utmost for lysimeter-C and lowest for lysimeter-B. In addition, the findings of [8] stated that conductivity value is maximum in open dump lysimeter and values are lower in sanitary landfill lysimeter. It may cause for different bottom layers and different top layer's thickness and types.

Sulfate Concentration: The mean sulfate concentration was the maximum in lysimeter-D and minimum in lysimeter-A. The Figure 6 illustrates that sulfate concentration for all lysimeters was escalating from 1540 - 1820, 1620 - 1855, 1650 - 1890 and 1810 - 2015 mg/L for lysimeter B, C, D and A, respectively, up to 50 days leisurely. Concentration of sulfate primarily increased due to brisk Sulfate degradation. Sulfate degradation has a higher energy benefit for organism [8] which are responsible for the waste decomposition. So degradation of Sulfate initially, provided additional energy for organism that increased the waste decomposition and produced more amount of leachate at the latter stage. As a result, after 50 days unsurprisingly the concentration of sulfate in case of all lysimeters decreased due to dilution effect because of high amount of leachate generation. Moreover, the rapid decrease of sulfate is a result of predominately anaerobic condition in solid waste landfill under which sulfate is reduced to sulfide [21]. As mean sulfate concentration was the maximum for lysimeter-A and it produced maximum amount of leachate so cumulative amount of sulfate load was the highest from it and lowest from lysimeter-B. Soil can absorb different sulfate substance and sulfate ions. As a result, lysimeter using no top cover produce maximum amount of sulfate. It is striking to note that a linear relationship may be recognized between pH and Sulfate concentration. That is, Sulfate concentration increases when pH increases and vice-versa (Figure 4). A study conducted by [8] reported that pH increases while, sulfate-chlride ratio increases. Increase of sulfate – chlride ratio means increase of sulfate concentration. Hence the relationship between pH and sulfate is supported by [8]. Based on above explanation it is proved that landfill operational mode should be sanitary with a sandy loam soil as top cover.

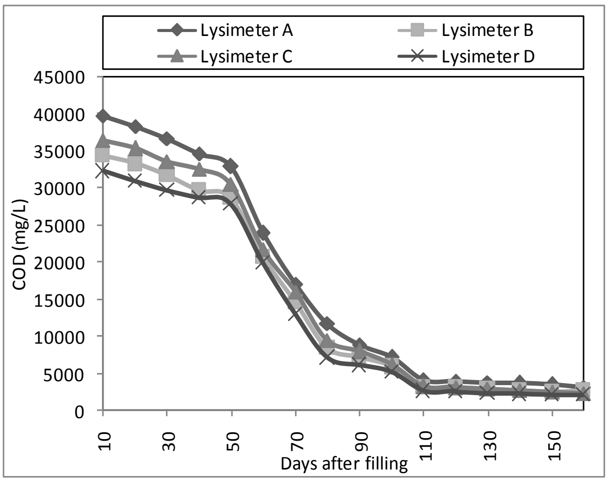


Figure 10 Variation of COD in landfill lysimeterat varying operational condition

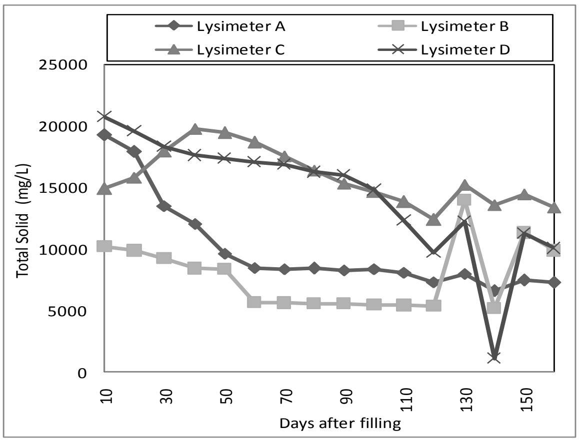


Figure 11 Variation of total solid in landfill lysimeter at varying operational condition

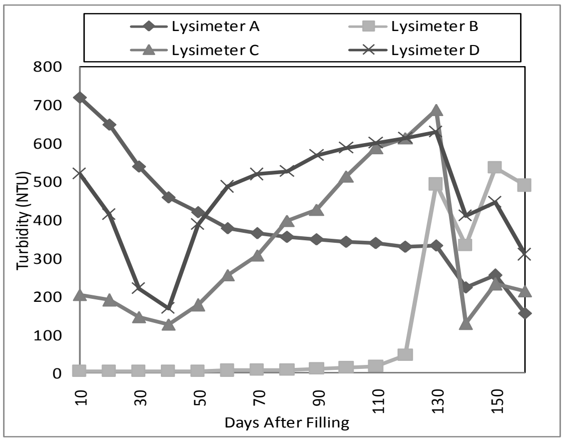


Figure 12 Variation of turbidity in landfill lysimeter at varying operational condition

Chloride Concentration: Table 3 explains that the middling value of chloride is the uppermost for lysimeter-B and lowest for lysimeter-A. The cover soils in different lysimeters may contain different salts and thus choride concentration is found higher in lysimeter using top cover compared to open dump lysimeter. Though the concentration of chloride is the highest for lysimeter-C but from Table 5, cumulative amount of chloride load leachated during 150 days was the lowest for lysimeter-C and highest for lysimeter-A. Figure 7 indicates that for all lysimeters, chloride concentration was climbing up to earliest 30 days from 3510 – 3830, 3180 – 3745, 3400 – 3770, 2910 – 3525 mg/L with the increment of pH in leachate. [22] suggested that as a result of the increase of pH in leachate, the dissolution of chloride increases and thus the chloride in leachate also increases. So the findings are supported by [22]. After that concentration was falling up to 90 days from 3830-1045, 3745-860, 3770-780 and 3525-640 mg/L when pH values were also decreasing. Due to high quantity of leachate generation in this stage, chloride concentration may be diluted [8]. After 90 days, concentration of chloride for all cncerned lysimeters was improved again. Here it is exciting to note that a relationship is found between chloride and TS.

Alkalinity Concentration: The alkalinity of water is due primarily to salts of weak acids and strong bases, and such substances acts as buffers to resist a drop in pH resulting from acid addition [4]. Table 3 reflects that mean alkalinity concentration is the maximum for lysimeter-D and minimum for lysimeter-B. It increase gradually in every lysimeter until addition of water but after recirculation it's amount decreases shown in Figure 8. Alkalinity is greater in lysimeter-D because for it's sorting of waste before dumping. In lysimeter-B clay bottom liner act a major role in the concentration of alkalinity. In leachate at a specific time, and in most of the cases, concentration increases during a relatively short initial phase then, decrease with time [23,24]. It may do in the time of 40-60 days. So the findings are valid according to [23, 24] also.

Biochemical Oxygen Demand : Biochemical Oxygen Demand (BOD) is the amount of oxygen consumed during microbial utilization of organics. By BOD test only biodegradable organics can be quantified while COD includes both biodegradable and nonbiodegradable organics. To quantify nonbiodegradable organics BOD must be subtracted from COD. So BOD is a portion of COD. From the Figure 9 it is evident that, surprisingly BOD values were increased initially even if COD values were decreased up to 30 days ranging from 17035-18220, 18234-19995, 19656-21060 and 21938-23465 mg/L. it may be due to increase of biodegradable organics with respect to nonbiodegradable organics. Then the values were found in increasing for next week. But after that, values were decreasing in manner like COD values predictably.

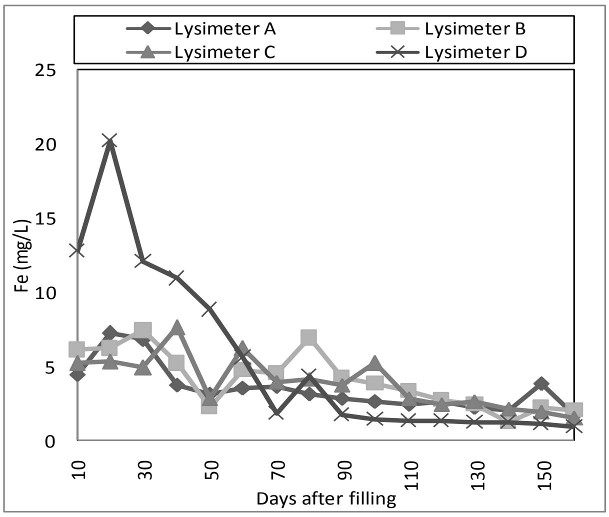


Figure 13 Variation of iron in landfill lysimeter at varying operational condition

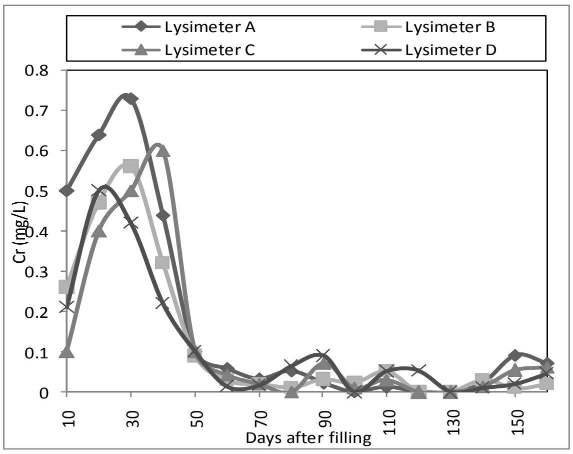


Figure 14 Variation of chromium in landfill lysimeter at varying operational condition.

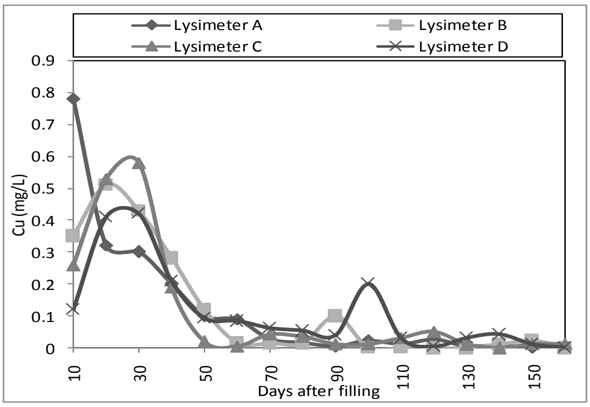


Figure 15 Variation of copper in landfill lysimeter at varying operational condition

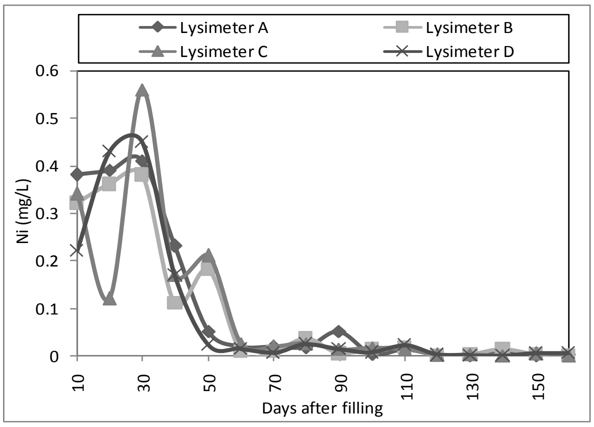


Figure 16 Variation of nickel concentration in landfill lysimeter at varying operational condition.

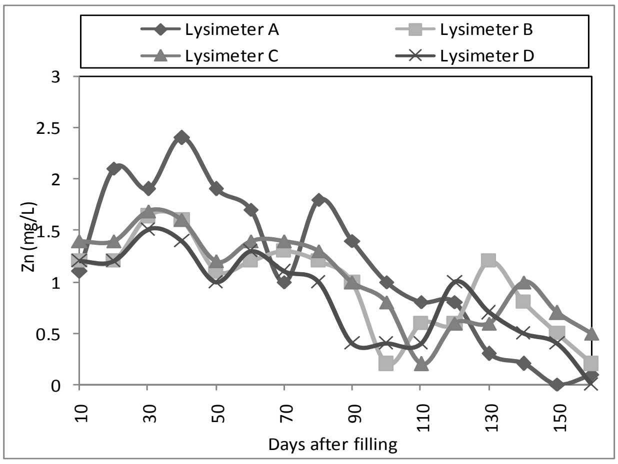


Figure 17 Variation of zinc concentration in landfill lysimeter at varying operational condition.

Chemical Oxygen Demand : Chemical Oxygen Demand (COD) is the measure of oxygen equivalent to the portion of organic matter which is susceptible to oxidation by Potassium Dichromate. COD is an important test and it gives a quick measurement of pollution load of the leachate. Therefore it is proved that an open dump landfill lysimeter-A, having no cover soil produced the most tainted leachate. COD concentration was found highest for the first sampling from all the concerned lysimeters and Subsequently, the graph was declining in nature up to 47 days unhurriedly from 32305 - 27920, 34460- 28740, 36505 - 30605 and 39725 - 32905 mg/L and then up to 89 days piercingly from 27920 - 2620, 28740 - 3110, 30605 - 3210 and 32905 - 4100 mg/L for lysimeter-B, C, D and A, respectively shown in Figure 10. COD decreases sharply between 50 to 90 days due to comparatively the higher rate of leachate production [8]. Due to the initial biodegrability and washout of MSW due to rainfall, COD decreases with the increasing age of landfill [21]. Moreover, the COD was seemed to be diluted due to the rainfall events and then decreases [17]; [25]. From 90th days, the graph was gradually declining in nature. A constant decrease in COD is also expected as degradation of organic matter continues [26]. So the findings are supported by [8,17,21,25,26]. Maximum COD was found from lysimeter-A and minimum was from lysimeter-B. A similar study conducted by [16] also found the same results. So the obtained values are precisely exact according to [16] also. Finally, it can be concluded that COD of landfill leachate can be diminished significantly by applying sanitary landfill operational mode and sandy loam soil as the cover soil of that operational system.

Total Solid Concentration and Total Solid Load

The average value of total solid (TS) in the leachate generated from lysimeter-B was significantly less than lysimeters-A, C and D. The higher concentrations of TS found from the lysimeters having presorted MSW. The TS depends on criterion of bottom layer soil. Such as clay have poor porosity so it blocks large amount particles in lysimeter-B , on the other hand gravel have large porosity so TS is greater in lysimeter-A. The bottom layer and top layer of lysimeter-C and D are same but waste is presorted before dumping in lysimeter-D. So TS is greater in lysimeter-D compared to lysimeter-C. After adding water in all lysimeter TS increase but after recirculation TS decreases. So leachate recirculation may be good treatment for leachate. The Figure 11 shows that for all lysimeters TS values were found decreasing upto 120 days from 19250 - 7308, 10174- 5374, 14900 - 12387 and 20750 - 9744 mg/L for lysimeters-A, B, C and D respectively. The concentration of TS of different lysimeters was decreased due to dilution effects because of high amount of leachate generation and one more explanation is reduction in availability of loose materials that can easily get dissolved with the percolating water with the increase in age of deposited waste due to compaction of waste [27]. Afterward the graph was gotten a stable state. After 100 days when no significant change was occurred in the concentration of TS indicates that the solids joining the leachate at the latter stage are the products of chemical and biological activities of waste [7]. So the findings are convincing according to [27] and [7]. Similar trend was also observed for the same cases of lysimeter studied conducted by [16]. Though the cover soil itself induced some solids in leachate initially but the ultimate TS load was recorded lower in sanitary landfill operational mode. Sandy loam soil as top cover in sanitary landfill produced the lowest amount of TS load and hence proved as more applicable soil in sanitary landfill.

Turbidity

Generally turbidity is proportional to total solid . But from experiment we found some variations. From Figure 12 we see lysimeter-A and B shows equivalent charecter, but in lysimeter-C it's turbidity decreases and then increases upto 40 days, after that turbidity increase but TS decrease simultaniously. In lysimeter-D upto 40 days both turbity and TS decrease but after that turbity increase rapidly. So turbidity not always depends on TS but also on various concentration as well. There might have no answer for this variation, further experiment will be needed to find this answer.

Iron (Fe) Concentration: The Table 3 and 5 explicate that the average iron concentration and cumulative amount of iron load leachated during 150 days were maximum from lysimeter-A while minimum from lysimeter-B. From Figure 13, iron concentration values were found higher in the early days for all of the concernd lysimeters when pH was low. The rate of Iron oxidation at the low pH level is increased by the presence of certain inorganic catalysts of through the action of micro-organisms. Soon after that, the concentration values were decreasing in nature. The concentrations of metals (Fe, Ca etc.) are expected to reduce as the leachate changes from acidogenic to methanogenic [1]. This expected decreasing trend is obvious in the Fe because of the sorption and precipitation that occur at higher pH values [1]. But at the latter stage when pH values were decreasing again but iron concentration values were not increasing for different lysimeters. Umar [28] suggested that as a result of decreased pH at later stages, a decrease in metal solubility occurs. So the findings are valid according to [1, 28]. Subsequently, Iron is removed in a great content in sanitary landfill operational mode with a sandy loam soil as top cover.

Heavy metals—Chromium, Copper, Nickel and Zinc

Usually, the heavy metal concentration in landfill or landfill lysimeter is fairly low [28]. Sorption and precipitation are the main causes for the low metal concentrations in landfill leachate [1]. Solid wastes contain soils and organic matter, which have a significant sorptive capacity, especially at neutral to high pH values prevailing in methonegenic leachate [29]. Heavy metal concentrations observed in this study are given in Figures 16-17 for chromium, copper, nickel and zinc concentrations, respectively. Figures confirm that concentration of different heavy metels in different lysimeters were found higher initially when the pH was low and in acidic range for all lysimeters. Concentration of heavy metal in landfill leachate is generally higher at earlier stage because of higher metal solubility as a result of low pH caused by production of organic acids [30]. Higher concentration of heavy metals initially was also found by [1]. Heavy metal concentration of leachate is a function of pH and carbonates. Heavy metal concentrations increase at low pH values and decreases when carbonate species increase [1]. Latter the concentration of different heavy metals were dropped down for all concerned lysimeters though the pH was in decreasing trend. Concentration of different metals may be watery because of high amount of leachate generation. Another reason is, as a result of decreased pH at later stages, a decrease in metal solubility occurs resulting in rapid decrease in concentration of heavy metals [28].

The maximum Cr concentration was found as 0.73 mg/L in lysimeter-A having no top cover and minimum is 0 mg/L from all concerned lysimeters shown in Figure 14. But from average value of Cr concentration for all concerned lysimeters it can be stated that concentration was not so severe. The utmost Cr load at the end of the experiment was seen in lysimeter-A. Moreover, the average value of Cu shows no any significant difference among the lysimeters at different operational conditions. The maximum Cu concentration was found as 0.78 mg/L in lysimeter-A having no top cover and minimum is 0 mg/L from all concerned lysimeters shown in Figure 23. Moreover, Cu load was the maximum in lysimeter-A.

The maximum Ni concentration was seen in lysimeter-C and recorded as 0.56 mg/L, while, minimum value was 0 mg/L from all operational mode shown in Figure 24. In addition, Ni load was calculated as highest in lysimeter-A. In contrary, Zn concentration was recorded higher in lysimeter-A with respect to lysimeter-B, C and D shown in Figure 17. Moreover, Zn load was calculated as highest in lysimeter-A as well. Thus it can be stated that heavy metal leaching can be reduced by practicing sanitary landfill operational mode. Most importantly, clay as a bottom liner is the best option to reduce the leaching of heavy metals.

CONCLUSIONS

Result reveals that open dump lysimeter produced more quantity of leachate around 29%in contrast to the sanitary landfills. In addition, waste settlement rate in open dump lysimeter is the maximum contrary to the sanitary landfill lysimeters. Though open dump landfill operation concentration of all properties in leachate were found as the highest compared to sanitary landfills. Among all the lysimeters using cover soils, the lysimeter having soil type-1 as top cover had the lowest concentration and load of most of the leachate constituents and least amount of leachate as well, against the other counterpart i.e soil type-2. Compacted clay as bottom liner give best solution in controlling concentration of pollutants. In conclusion, it can be concluded that a strategic plan for sustainable landfill with low cost could be achieved by upgrading open dumping practice to engineered landfill in different south Asian countries like Bangladesh, India and so on. In engineered landfill, a soil having more sand percentage is the most suitable soil to be used as a cover soil and clay soil as a bottom soil proved best due to its significant pollutant reduction capacity from most tainted liquid leachate.

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