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Statistical Analysis of Leachate Characteristics in Pilot Scale Landfill Lysimeter

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Abstract: The objective of this study was to analyze the characteristics of leachate in pilot scale landfill lysimeter for inorganic and organic compounds as well as metal and heavy metal concentrations against their operational conditions based on statistical tool through statistical package for social science (SPSS) software. To these attempts, three pilot scale landfill lysimeter test facilities were set-up at KUET campus, Bangladesh. Three different situations of landfill were considered here, however, both the sanitary landfill and open dump conditions having a base liner and two different types of cap liner were simulated. The simulated lysimeters were maneuvered at different operational conditions of leachate detection (A_1) and collection (A_2) system of open dump lysimeter-A as well as the leachate collection system of sanitary landfill lysimeter-B and C. Based on the evaluated results it was observed that the physical, chemical and biological characteristics of the leachate varied significantly for different condition of construction materials used as cap and base liner in lysimeter. The reveled results of leachate characteristics were analyzed by statistical tool such as Analysis of Variance (ANOVA) and correlations has also been evaluated and discussed. For analyzing the leachate data, the confidence level 95% for ANOVA was considered.

Keywords:

1. Introduction:

The municipal solid waste (MSW) refers to the materials discarded in the urban areas for which municipalities are held responsible for collection, transport and final disposal (Alamgir et al., 2005). The management tier of MSW mainly prominence on waste generation, source storage and segregation, collection, transport and finally the ultimate disposal site. There are two options for MSW dumping all over the world; one is open dumping another is sanitary landfill (WasteSafe 2005). The term 'landfill' is used herein to describe a unit operation for final disposal of 'municipal solid waste (MSW)'on land, designed and constructed with the objective of minimum impact to the environment. This term encompasses the other terms such as 'secured landfill' and 'engineered landfills' which are also sometimes applied to MSW disposal units (Tubtimthai 2003). The term 'landfill' can be treated as synonymous to 'sanitary landfill' of MSW, only if the latter is designed on the principle of waste containment and is characterized by the presence of a liner and leachate collection system to prevent ground water contamination. Sanitary landfill is one of the secure and safe facilities for the disposal of MSW; however, it needs high standard of environment protection in the operation of landfill (Davis and Cornwell 1998). Moreover, it is a well-suited method for managing of MSW all over the world and to investigate the performance of sanitary landfill the behavioral patterns namely; leachate generation, landfill gas (LFG) emissions etc. are required (Visvanathan et al. 2002).

The word Lysimeter is a combination of the two Greek words "Lusis" means "Solution" & "Metron" means "Measure" and the original aim was to measure water balance (Rafizul et al., 2009). Based on this concept and to investigate the performance of both the base and cap liners made of Compacted Clay Liner (CCL), three lysimeter (designated as A, B and C) as a control mechanism test set-ups were designed and hence constructed at KUET campus, Khulna, Bangladesh.

The produced leachate in municipal solid waste (MSW) disposal sites is considered as one of the highly contaminated resources from physical, chemical and biological point of view. A number of incidences have been reported in the past, where leachate had contaminated the surrounding soil and polluted the underlying ground water aquifer or nearby surface water bodies (Rafizul et al. 2009). However, the best possible knowledge of leachate characteristics at a specific site is an essential management tool. This is not only important for new containment landfills, where leachate will be extracted and treatment/disposal facilities must be designed in advance, but also important for the old landfill sites, where the environmental safeguards rely on the natural attenuating properties of the geological strata, in both saturated and unsaturated zones beneath them, to reduce levels of contaminants to the levels where they pose minimal threats to environment (Robinson et al. 1992). Regulations usually require the MSW to be placed above the water table and not directly overlying the aquifer. In this environment, moisture may infiltrate through the top, generally resulting in an unsaturated flow through the refuse; leachate is then generated through the complex physical and biochemical processes and is transported to the underlying strata. In that manner leachate may pose a severe pollution threat to ground water supplies (Kelly et al. 1976).

To analyze the lysimeter leachate characteristic through statistical measurement has been done by a one-way ANOVA test. This one-way ANOVA test was completed using the SPSS 16.0. The different sampled landfill leachate concentrations were placed into the program to determine, which mean concentrations in the leachate parameters were significantly different from one another. The ANOVA test was used because it has no restriction on the number of means.

Table 1: *Operational conditions of lysimeter to simulate different landfill conditions*

<table>
<tr><th>Lysimeter</th><th>Operating condition</th><th>Refuse (kg)</th><th>Liner specification</th><th>Simulation</th></tr>
<tr><td rowspan="2">A</td><td>Open dump lysimeter with leachate detection (A_1) system</td><td rowspan="2">2860</td><td rowspan="2">400mm thick CCL as a barrier between leachate detection and collection system of lysimeter-A</td><td rowspan="2">present practice of open dumping</td></tr>
<tr><td>Open dump lysimeter with leachate collection (A_2) system</td></tr>
<tr><td>B</td><td rowspan="2">Sanitary landfill lysimeter with gas collection and leachate recirculation system</td><td>2985</td><td>Cap liner-I (300mm thick CCL)</td><td rowspan="2">applicability of designed top cover</td></tr>
<tr><td>C</td><td>2800</td><td>Cap liner-II (900mm thick natural top soil)</td></tr>
</table>

2. Overview of landfill lysimeters at KUET campus: Three landfill lysimeters designated as A, B and C were designed and hence constructed at KUET campus, Bangladesh based on a reference cell shown in Figure 1, showing all the design components in details. The operational condition, liner specifications, simulation behavior and the total weight of MSW deposited in each lysimeter are presented in Table 1. Three cylindrical lysimeter having outer diameter of 1.98 m and inner diameter of 1.48 m, with a height of 3.35m, and a leachate collection tank (3.68mx1.56mx1.64m) accommodating four separate leachate discharge pipes in the temporary collection and storage containers, were constructed using 250mm thick brick wall resting on a 250mm thick of reinforced cement concrete mat foundation at a depth of 760mm below the existing ground surface. The lysimeter were plastered inside and outside with two coatings of waterproofing agent to avoid leakage and corrosion due to acidic environment. The MSW deposited in lysimeter mainly consists of 93 (w/w) organic (food and vegetables), 3 (w/w) of plastic/polythene and 2 (w/w) of leather/rubber, 1 (w/w) of animal bone and rubber/leather as well as 1 (w/w) of rope/straw and egg pill. However, the organic content and moisture content of MSW was found 52 and 65%, respectively, and the total volume was 2.80m^3 (height 1.6m) with a manual compaction to achieve the unit weight of 1,064kg/m^3. At the bottom of each landfill lysimeter, a concrete layer of 125mm thickness was provided then the lysimeters were filled with stone chips (diameter 5-20mm) and coarse sand (diameter 0.05-0.4mm) to the height of 15cm of each to ensure uniform and uninterrupted drainage. At the base of each landfill lysimeter after placing the perforated leachate collection pipe, a geo-textile sheet having 0.60m wide and 1.65m length was placed on the top to avoid a rapid clogging of this perforated pipe by the sediments from the lysimeter.

Moreover, the type and volume of MSW deposited in open dump lysimeter-A was exactly the same as deposited in the reference cell. In open dump lysimeter-A, a compacted clay liner (CCL) of 400mm thickness was placed as the base liner and a layer of compost of 150mm thick was used as the top cover to simulate the behavior of present practice of open dumping in Bangladesh (Table 1). In this lysimeter the MSW was not covered by a top cover system to pervert the movement of air, water and generated 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 an open dump landfill condition comparing the counterparts i.e sanitary landfill lysimeter-B and C

In contrary, in sanitary landfill lysimeter-B (Figure 2), the characteristics and volume of the MSW is similar to that of the lysimeter-A and lysimeter-C. However, it differs with open dump lysimeter-A, by a top cover similar to that of Pilot Scale Sanitary Landfill (PSSL) constructed in Khulna without having a base liner, because this cell aims to examine the applicability of the designed top cover. The top cover consists of stone chips (diameter 5-20mm) and coarse sand (0.05-0.40 mm diameter) layer each of 100 mm thickness, then a 300 mm compacted clay liner (CCL). On the CCL, there were 150mm of coarse sand (0.4-.05mm diameter) and 150mm of stone chips (diameter 5-20mm), which was followed by 600mm thick top soil (Table 1). However, in sanitary landfill lysimeter-C, there was also no base liner and the top cover was different than that of the lysimeter-B. In this case no CCL was used; however, 900 mm topsoil was used instead of 300 mm CCL and 600 mm top soil (Table 1). But the drainage and gas collection layers remain same as the lysimeter-B. In both the lysimeters, 38mm diameter of gas collection and 25mm diameter of leachate recirculation pipe were installed. During the installation of these pipes and penetration through the top cover, special arrangements i.e. disc shaped rubber gasket were used to prevent the leakage of gas Designated compaction of the CCL in the lysimeter means the degree of compaction which was provided in the pilot scale sanitary landfill (PSSL) at Rajbandh, Khulna. To achieve the designated compaction at the CCL of lysimeter, locally manufactured hammer similar to that used in the PSSL was employed.

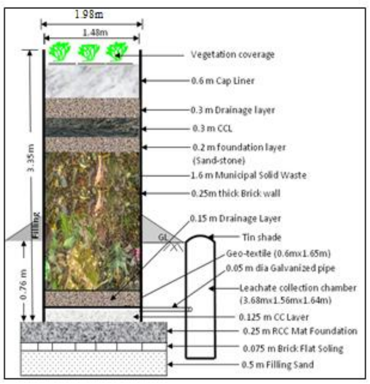

***Figure 1**: Schematic diagram of reference cell for landfill lysimeter design*

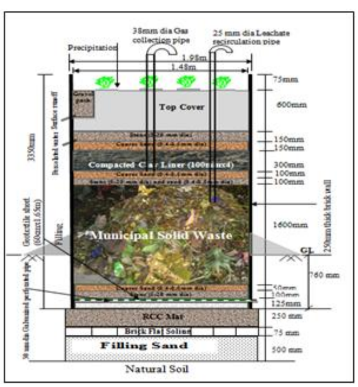

***Figure 2**: Schematic diagram of sanitary landfill lysimeter-B*

3. Characterization of materials used in this study:

The total weight of deposited MSW in lysimeter A, B and C were 2860, 2984 and 2798Kg, respectively, and total volume was 2.80m^3 (height 1.6m). The unit weight was obtained in the range of 1000-1064 kg/m^3. It can be depicted that the MSW deposited in lysimeter are characterized in the laboratory and the food and vegetable wastes was the predominant component and about 93(w/w). The moisture content was found of 65%. Result obtained from sieve analysis test is provided in Table 2.

***Table 2**: Sieve analysis of MSW deposited in lysimeter*

Finer fraction (%)				
300-200 mm	100 mm	76.2 mm	38.2 mm	19.1 mm
100	76.25	63.72	45.22	24.34

Based on the tests conducted on the clay which was used as liner, the moisture content, plastic limit, liquid limit, plasticity index, and shrinkage limit were found as 22, 22, 43, 21 and 16%, respectively. It is important to know the physical and mechanical properties of the soils as thoroughly as possible before assessing their physico-chemical or hydro-mechanical behavior (Rafizul et al. 2009). Moreover, Daniel (1995) a researcher stated that using clay as the CLL in solid waste landfill the following fundamental criteria to be satisfied such as coefficient of permeability (k≤1x10^{-7} cm/s), plasticity index (PI<7), water content (w%)>plastic limit (PL%) as well as at least 30% fines and 15% clay. In addition, the percentages of soil constituents were found as sand, silt and clay of 10, 56.6 and 33.4%, respectively, while, the value of optimum moisture content and maximum dry density of 18% and 16 kN/m^3, respectively and the coefficient of hydraulic conductivity of 1.90x10^{-7} cm/sec. The mineralogical compositions of clay used as CCL as shown in Table 3 as measured in the laboratory of the Department of Applied Geology, Karlsruhe University, Germany (Roehl, 2007) .

***Table 3**: Mineralogical compositions of clay used as CCL in lysimeter (Roehl, 2007)*

Minerals (amount in weight-%)		Sample (0-7m)	Sample (13-23m)
Non-clay minerals	Quartz	19%	17%
	Feldspars	<1%	<1%
	Carbonates	<1%	<1%
Non-swelling clay minerals	Illite	~50%	~50%
	Kaolinite	~10%	~10%
	Chlorite	<1%	1-2%
Swelling clay minerals: Smectite		20%	19%

4. Methodology adopted:

In lysimeter the leachate generation rate is mainly influenced by climate such as rainfall and evaporation in which the lysimeter were situated and it depends on the initial moisture content of MSW amongst others (Rafizul et al. 2012). Leachate samples were analyzed for physico-chemical parameters of pH by pH meter

(HACH, Model No. Sens ion 156), alkalinity by titration method, hardness by EDTA titrimetric method as well as COD by closed reflexive method as per the Standard Methods (APHA, 1998). However, the Ca, Na, K and Mg ions were determined using flame atomic absorption spectrophotometer (VARIAN; AA/2400) with proper standard calibrations. In addition, Heavy metals viz., Cu, Cr, Cd, Ni, Pb, Mn, Fe and Zn were analyzed using spectrophotometer (HACH; DR/2400) as per the Standard Methods (APHA, 1998).

ANOVA has been conducted on the relevant parameters in leachate using the following assumption-

- Each landfill was independent of one another and
- The data has the same variance, they were positively skewed.

After completing the one-way ANOVA test, a Turkey's test was also conducted because it is the most commonly used Post Hoc analysis test.

5. Results and discussions:

On the basis of experimental results obtained by conducting several tests on the collected leachate sample in the laboratory, results were obtained and hence discussed in followings.

5.1 Variation of Organic and Inorganic Compounds:

The variation of inorganic compound in terms of pH, alkalinity and hardness as well as the organic carbon of COD at varying elapsed period were analyzed and hence discussed in the following articles.

5.1.1 pH:

The variation of pH with respect to the elapsed period and operational conditions for both the open dump lysimeter-A and sanitary landfill lysimeter-B and C is provided in Figure 3. From Figure 3, it can be signified that detection system of open dump lysimeter-A had the highest pH with 8.47 than that of collection system at the waste deposition period of 6 weeks then gradually decreased. In case of present study, pH in leachate varied from 5.88-8.75 and the maximum concentration of pH was found for collection system of lysimeter-A of 8.75.

Table 4 shows the output of the ANOVA analysis using the Post Hoc (Turkey HSD) test with the statistically significant difference between the lysimeter operational conditions. Here, Table 3 reveals that in case of A_1 and A_2 system of open dump lysimeter-A, the significance level is 0.001, which is below 0.05 and, therefore, there is a statistically significant difference. Here, it can be established that the variation of pH in case of A_1 and A_2 system of open dump lysimeter-A may be occurred due to the providing of 400mm thick CCL as a barrier between the A_1 and A_2 system of lysimeter-A. As the A_2 provided just below the MSW deposited in lysimeter-A and the followed A_1 was separated with the 400mm thick CCL and this operational mode may be considered for the variation of pH between these two systems.

Table 4: *One-way ANOVA analysis for pH*

Multiple Comparisons

Dependent Variable:Value of Ph

	(I) Lysimeter group	(J) Lysimeter group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	A1	A2	-.48325*	.12555	.001	-.8093	-.1572
		B	-.65025*	.12555	.000	-.9763	-.3242
		C	-.71150*	.12555	.000	-1.0375	-.3855
	A2	A1	.48325*	.12555	.001	.1572	.8093
		B	-.16700	.12555	.545	-.4930	.1590
		C	-.22825	.12555	.269	-.5543	.0978
	B	A1	.65025*	.12555	.000	.3242	.9763
		A2	.16700	.12555	.545	-.1590	.4930
		C	-.06125	.12555	.962	-.3873	.2648
	C	A1	.71150*	.12555	.000	.3855	1.0375
		A2	.22825	.12555	.269	-.0978	.5543
		B	.06125	.12555	.962	-.2648	.3873
Games-Howell	A1	A2	-.48325*	.11508	.000	-.7854	-.1811
		B	-.65025*	.12568	.000	-.9803	-.3202
		C	-.71150*	.12904	.000	-1.0504	-.3726
	A2	A1	.48325*	.11508	.000	.1811	.7854
		B	-.16700	.12196	.522	-.4874	.1534
		C	-.22825	.12542	.272	-.5578	.1013
	B	A1	.65025*	.12568	.000	.3202	.9803
		A2	.16700	.12196	.522	-.1534	.4874
		C	-.06125	.13521	.969	-.4162	.2937
	C	A1	.71150*	.12904	.000	.3726	1.0504
		A2	.22825	.12542	.272	-.1013	.5578
		B	.06125	.13521	.969	-.2937	.4162

*. The mean difference is significant at the 0.05 level.

Similarly in case of A_2 system with respect to lysimeter-B and C, the significance level is 0.545 and 0.269, respectively, which is above 0.05, therefore, it shows homogeneity of variances. In contrary, In case of sanitary lysimeter-B, the statistically significant level is 0.962, which is above 0.05 with respect to sanitary lysimeter-C, therefore, it shows homogeneity of variances.

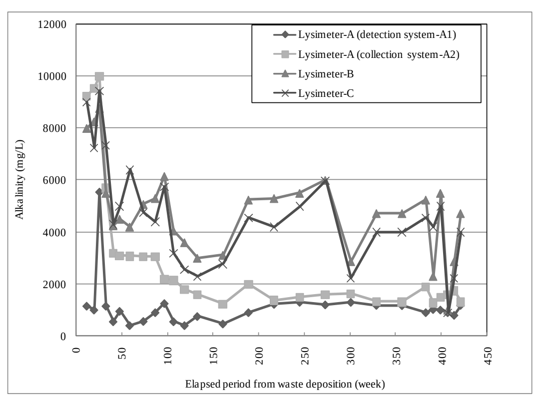

Figure 3*: Variation of pH with elapsed period*

5.1.3 Alkalinity:

The variation of alkalinity in leachate is provided in Figure 4. Figure 4 reveals that alkalinity was significantly decreased in the range of 8000-1111.2 mg/L and 9000-2278 mg/L for lysimeter-B and C, respectively, up to the deposition period close to 23 weeks. The Alkalinity varied from 1111.2 - 9000 mg/L. The variation of Alkalinity is due to the difference of two lysimeters in terms of thickness of cap liner and its compaction condition. In contrast, alkanility for the collection system of sanitary landfill lysimeter-B and C may be occurred due to the difference of landfill lysimeter-B and C in terms of thickness and compaction conditions of cap liner.

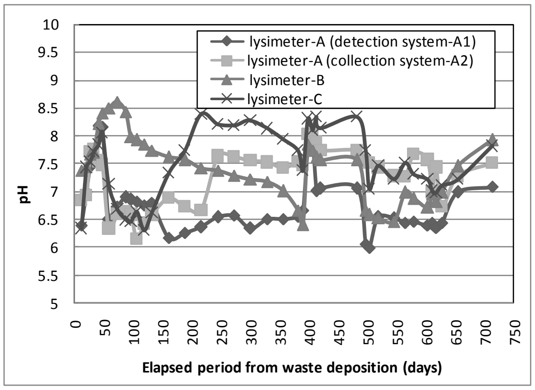

Figure 4*: Variation of Alkalinity with elapsed period*

From one way ANOVA test with obtained data it was found that, there was a significant difference with alkalinity between the landfills. Using the Post Hoc test, it showed that lysimeter-A_1 was significantly different from lysimeter-B and C. In contrary, In case of sanitary lysimeter-A_1, the statistically significant level with lysimeter B and C is 0.000,and 0.000 respectively which is below 0.05, therefore, it shows difference in variances. No significant difference was found between others.

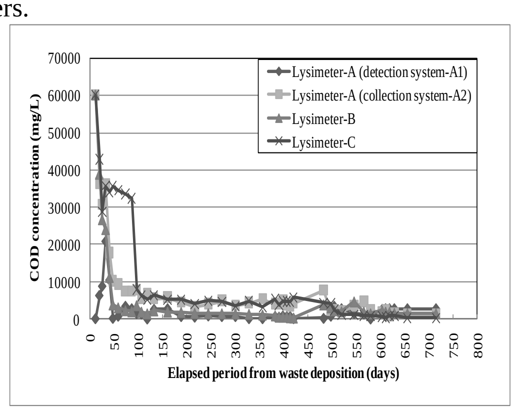

Figure 5*: Variation of COD concentration with elapsed period*

5.1.4 COD concentration:

The concentration of COD in leachate was significantly decreased in the range of 60,000-800 mg/L and 60,000- 1280 mg/L for the collection system of sanitary landfill lysimeter-B and C, respectively, up to the elapsed period of 23 weeks shown in Figure 5. A decrease of COD occurs over the elapsed period of landfill and it can be attributed to a combination of reduction in organic contaminants and the increased biodegradation of organic compounds (Krug and Ham 1995). A constant decrease in COD is also expected as degradation of organic matter continues (Ehrig 1989). Diaz (1996) introduced that the concentration of COD varied from 0-89,520mg/L of leachate generated from MSW in landfill. Diaz (1996) introduced that the concentration of COD varied from 0-89,520 mg/L of leachate generated from MSW in landfill.

From one way ANOVA test with obtained data it was found that, there was a significant difference with COD concentration between the landfills. Using the Post Hoc test, it showed that, lysimeter-A_1 and C showed significant difference between them. No significant difference was found for others.

5.1.5 Hardness:

Figure 6 represents the hardness in leachate and it significantly decreased in the range of 10,000-1852 mg/L, 14,000-1344 mg/L and 10,000-1324 mg/L for the collection systems of lysimeter-A, B and C, respectively, up to the deposition period of 17 weeks and then it was increased up to the waste deposition period of 23 weeks for both the cases. Diaz (1996) introduced that the values of Hardness varied from 0-22,800 mg/L of leachate generated from MSW in landfill.

From one way ANOVA Using the Post Hoc test with obtained data it was found that, there was no significant difference for hardness between the landfills as significance level was obtained above 0.05 for all the cases.

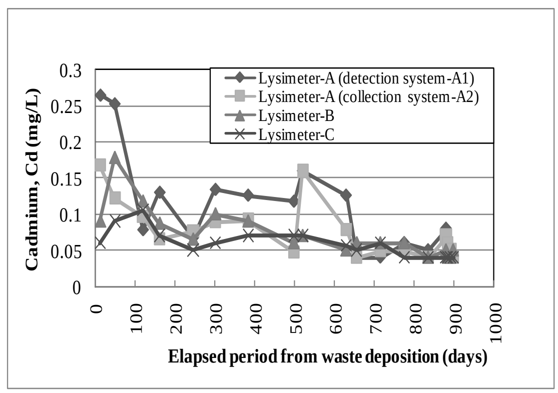

Figure 6*: Variation of hardness with elapsed period*

5.2 Variation of Metal Concentrations:

5.2.1 Potassium:

Potassium concentration was ranging of 855.9-1967.0 mg/L, 1102.1-2589.0 mg/L, 1008.6-1764.3 mg/L and 567.2- 1956.7 mg/L, for leachate detection (A_1) and collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 7. At the beginning of lysimeter operation, **p**otassium concentration was determined as 1650.5 and 1815.8 mg/L and after 50 day, it was dropped markedly to 855.9 and 1576.8 mg/L, and at 500 day, it was reached as maximum values of 1370 and 2590 mg/L, for leachate detection (A_1) and collection system (A_2) of lysimeter-A, respectively.

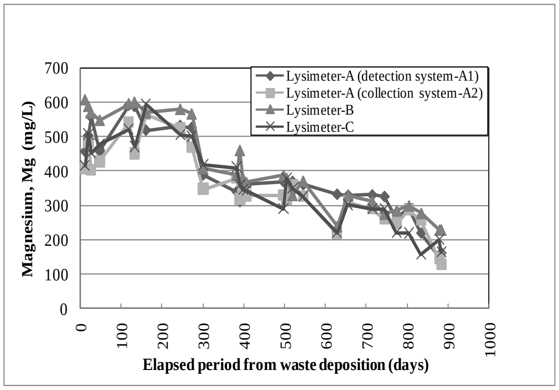

***Figure 7**: Variation of potassium concentration with elapsed period*

From one way ANOVA test with obtained data it was found that, there was a significant difference with Potassium between the landfills. Using the Post Hoc test, it showed that, lysimeter-A_2 showed significant difference with rest of the lysimeters.

5.2.2 Calcium:

Calcium was ranging from 253.5-789.9 mg/L, 217.9-664.2 mg/L, 153.0-578.0 mg/L and 140.0-664.4 mg/L, for leachate detection (A_1) and collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 8. The highest concentration of Ca was measured in leachate detection (A_1) system of lysimeter-A with 789.9 mg/L, whereas, the lowest of 140 mg/L for lysimeter-B. On the other side, Ca concentration was decreased rapidly below 400 mg/L after day 300 in both the cases of leachate detection (A_1) and collection system (A_2) of lysimeter-A. However, causes a slow decrease in Ca concentration for both the cases of lysimeter-B and C, and markedly decreased around 200 mg/L after day 650.

From one way ANOVA test with obtained data it was found that, there was no significant difference with calcium between the landfills. Using the Post Hoc test, it showed that, all the combinations have significance level greater than 0.05.

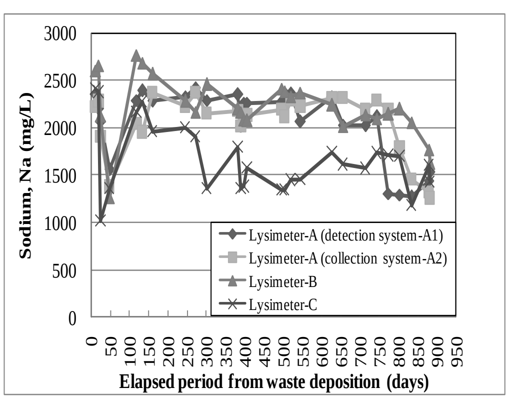

***Figure 8**: Variation of calcium concentration with elapsed period*

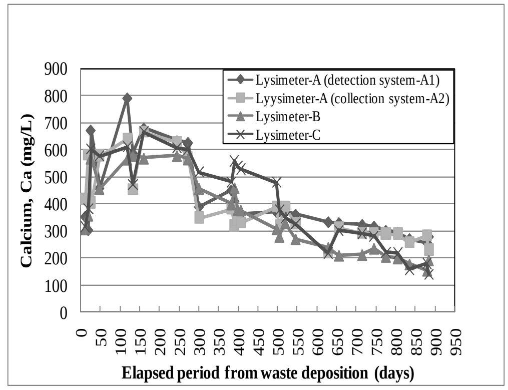

***Figure 9**: Variation of sodium concentration with elapsed period*

5.2.3 Sodium:

Sodium concentration was ranging of 1267.9-2424 mg/L, 1251.6-2369.6 mg/L, 1256.3-2764.3 mg/L and 1011.9- 2409.1 mg/L, for leachate detection (A_1) and collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 9. The highest concentration of Na was measured in case of lysimeter-B with 2764.3 mg/L, whereas, the lowest of 1011.9 mg/L in lysimeter-C. In contrast, Na for the collection system of sanitary landfill lysimeter-B and C may be occurred due to the difference of landfill lysimeter-B and C in terms of thickness and compaction conditions of cap liner.

From one way ANOVA test with obtained data it was found that, there was a significant difference with sodium between the landfills. Using the Post Hoc test, it showed that, lysimeter-C showed significant difference with the rest of the lysimeter operation conditions as significance level was above 0.05.

5.2.4 Magnesium:

Figure 10 represents the concentration of magnesium and it was ranging from 147.25-589.9 mg/L, 127.15-564.2 mg/L, 228.4-605.9 mg/L and 156-594.2mg/L, for leachate detection (A_1) and collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively. At the beginning of the aerobic landfill lysimeter operation, Mg concentration was determined as 455.7 and 405.5 mg/L and at 120 day operation, it reached as maximum values of 589.9 and 540.6 mg/L for leachate detection (A_1) and collection system (A_2) of lysimeter-A, respectively.

From one way ANOVA test with obtained data it was found that, there was no significant difference with magnesium between the landfills. Using the Post Hoc test, it showed that, all the combinations have significance level greater than 0.05.

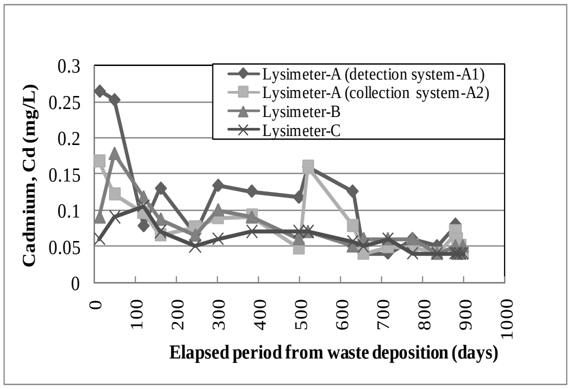

Figure 10*: Variation of magnesium concentration with elapsed period*

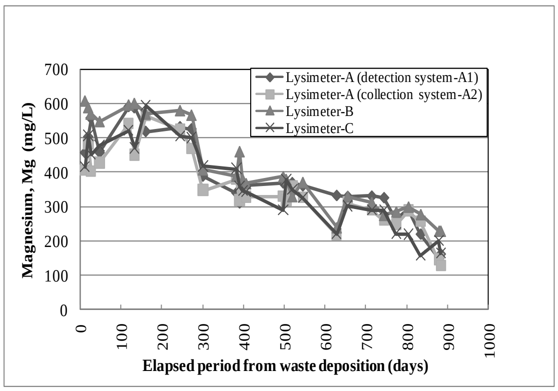

Figure 11*: Variation of cadmium concentration with elapsed period*

5.3 Variation of Heavy Metal Concentrations:

5.3.1 Cadmium:

Cadmium concentration was measured in the range of 0.04-0.265, 0.04-0.168, 0.04-0.178 and 0.04-0.105 with in relation to the changing of elapsed period from waste deposition, for leachate detection system (A_1), leachate collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 11. The Cd concentration was found 0.265 and 0.168 mg/L, and after 120 day, it was decreased markedly 0.078 and 0.097 mg/L, for leachate detection (A_1), leachate collection system (A_2), respectively. At the day of 660 to until the end of this trial, there was no significance change for cadmium.

From one way ANOVA test with obtained data it was found that, there was a significant difference with cadmium between the landfills. Using the Post Hoc test, it showed that, lysimeter-C showed significant level with the lysimeter-A_1 as significant level exceeded 0.05.

5.3.2 Copper:

Copper concentration was measured in the range of 0.04-0.98, 0.04-0.97, 0.04-0.76 and 0.04-0.60 with in relation to the changing of elapsed period from waste deposition, for leachate detection (A_1), leachate collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 12. At the beginning Cu concentration was found 0.04 and 0.04 mg/L, and after 100 day operation, it was increased rapidly up the day of operation 500, 0.98 and 0.97 mg/L, for the leachate detection (A_1), leachate collection system (A_2), respectively. At the day of 630 and 775 to until the end of this trial, it was decreased rapidly for both the cases of lysimeter-A system.

From one way ANOVA test with obtained data it was found that, there was no significant difference with copper between the landfills. Using the Post Hoc test, it showed that, significance level between lysimeters was above 0.05.

5.3.3 Chromium:

Figure 13 revels that, at the beginning of lysimeter-A operation, chromium concentration was found 0.065 and 0.06 mg/L, for leachate detection (A_1) and leachate collection system (A_2), respectively. After 120 days, Cr concentration was decreased as 0.02 and 0.02 mg/L for both the cases, and after 120 day to end of this trail, the leachate detection system showing the higher than the leachate collection system.

From one way ANOVA test with obtained data it was found that, there was a significant difference with chromium between the landfills. Using the Post Hoc test, it showed that, lysimeter-A_2 and B showed significant difference with them. Rest of the combinations was insignificant.

5.3.4 Manganese:

Manganese concentration was ranging of 0.80-6.0, 2.5-21.2, 0.50-19.3 and 0.80-8.0 mg/L, with in relation to the changing of elapsed period, for the leachate detection (A_1), leachate collection system (A_2), lysimeter-B and C, respectively shown in Figure 14. However, the highest concentration of Mn was found for the collection system of lysimeter-A as 21.2 mg/L and both the lysimeter operation showing almost the same concentration of Mn. From one way ANOVA test with obtained data it was found that, there was no significant difference with manganese between the landfills. Using the Post Hoc test, it showed that, , significance level between lysimeters was above 0.05

5.3.5 Nickel:

Nickel concentration was ranging of 0.04-0.075, 0.04-0.055, 0.04-0.09 and 0.04-0.07 with in relation to the changing of elapsed period, for leachate detection (A_1), leachate collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 15. From the beginning of lysimeter-A operation up to the day of 520, nickel concentration increased remarkably and reached to the values of 0.09 and 0.07 mg/L, and after 520 day operation, it was dropped, for lysimeter-B and C, respectively.

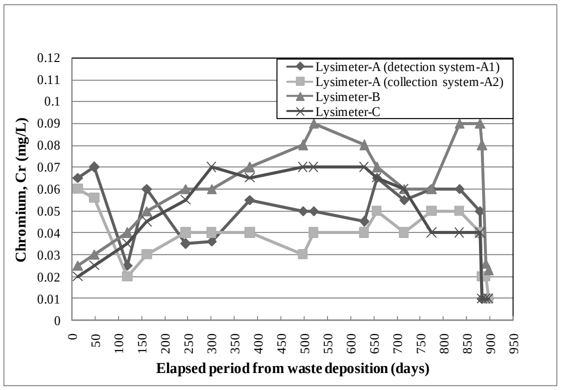

***Figure 12**: Variation of copper concentration with elapsed period*

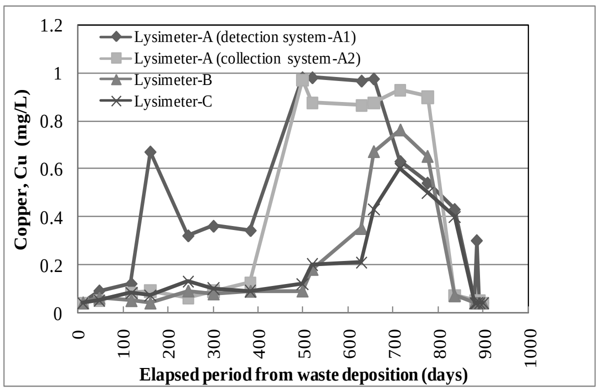

***Figure 13:** Variation of chromium concentration with elapsed period*

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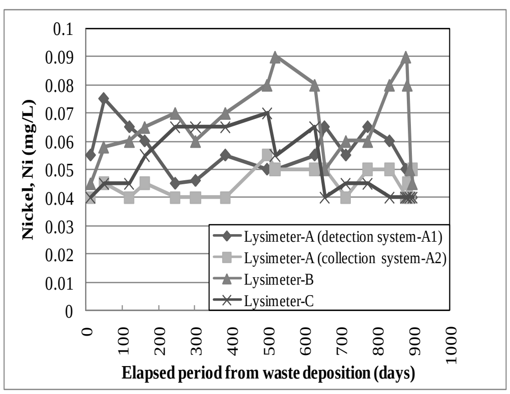

***Figure 14**: Variation of Manganese concentration with elapsed period*

From one way ANOVA test with obtained data it was found that, there was significant difference with nickel between the landfills. Using the Post Hoc test, it showed that, lysimeter-B has significance difference between all the lysimeters.

5.3.6 Zinc:

Zinc concentration was ranging of 0.25-1.267, 0.15-0.97, 0.10-0.55 and 0.10-0.576, with in relation to the changing of elapsed period, for leachate detection (A_1), leachate collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 16. From the beginning of lysimeter-A operation up to the day of 380, the Zn concentration was increased rapidly with 0.55 and 0.576 mg/L, for lysimeter-B and C, respectively.

From one way ANOVA test with obtained data it was found that, there was a significant difference with zinc between the landfills. Using the Post Hoc test, it showed that, lysimeter-A_1 and A_2 showed significant difference with B and C. Rest of the combinations were insignificant.

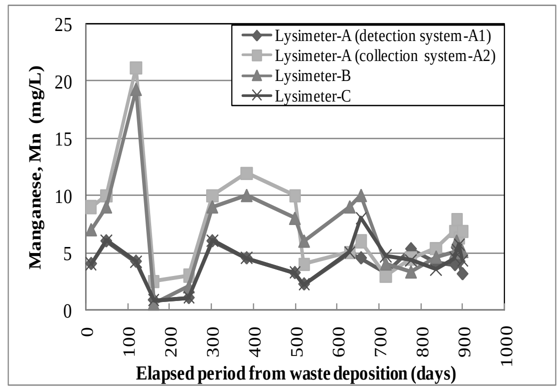

***Figure 15**: Variation of Nickel concentration with elapsed period*

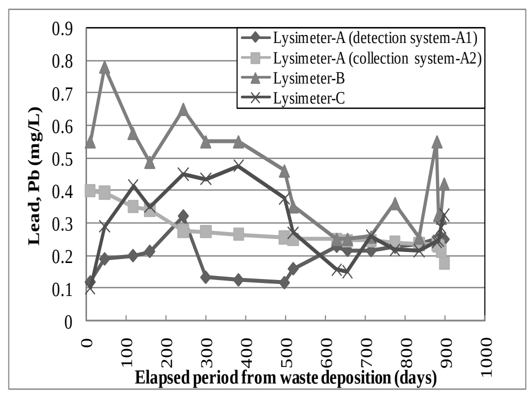

***Figure 16**: Change of zinc concentration with elapsed period*

5.3.7 Lead:

The lead concentration was ranging of 0.12-0.32, 0.12-0.397, 0.25-0.78 and 0.10-0.476 mg/L, with in relation to the changing of elapsed period, for the leachate detection (A_1), leachate collection system (A_2) of lysimeter-A, lysimeter-B and C, respectively shown in Figure 17. The highest concentration of Pb was measured in lysimeter-B with 0.78 mg/L, whereas, the lowest of 0.12 mg/L in both the cases of leachate detection system of lysimeter-A and the lysimeter-C and the concentration of Pb was differed regarding to entire lysimeter operation system.

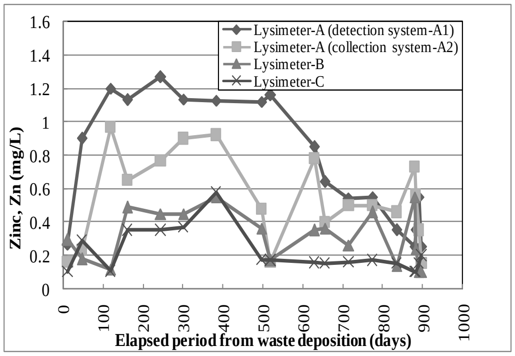

Figure 17: *Change of lead concentration with elapsed period*

From one way ANOVA test with obtained data it was found that, there was a significant difference with lead between the landfills. Using the Post Hoc test, it showed that, lysimeter-B showed significant difference with all the lysimeters. No significant difference between the rest.

5.3.8 Iron:

The values of Iron of leachate in case of lysimeter-C was found as 72.0mg/L which was higher than that of lysimeter-B of 11.2mg/L at the deposition period of 2weeks, then sharply decreased up to the period of 9 weeks for both the cases and after that it was increased up to the elapsed period of 10 weeks then also decreases shown in Figure 18. In case of lysimeter-C, the Iron has changed significantly in the range of 72.0-3.33mg/L and for lysimeter-B of 11.2- 2.22mg/L for the increase of waste deposition period from 2 to 4weeks. The variation of Iron is due to the difference of lysimeter-B and C in terms of thickness and compaction condition of cap liner.

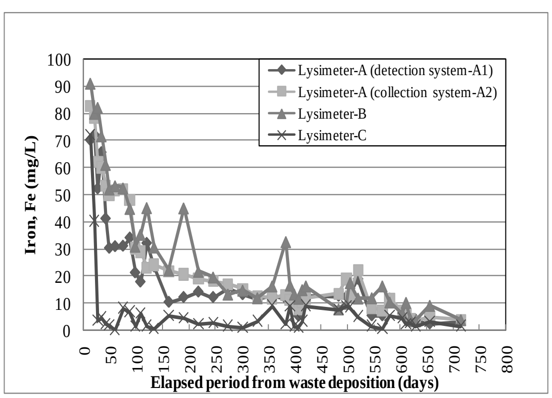

Figure 18*: Variation of Iron concentration with elapsed period*

From one way ANOVA test with obtained data it was found that, there was a significant difference with lead between the landfills. Using the Post Hoc test, it showed that, lysimeter-C showed significant difference with all the lysimeters. No significant difference between the rests.

6. Conclusions:

Based on experimental results, it was observed that leachate quality were varied in relation to the increasing of elapsed period from waste deposition in lysimeter as well as the specific variations of local civil engineering materials used for the construction of landfill lysimeter. Moreover, the result from ANOVA test reveals that leachate qualities were varied significantly with the variation of entire lysimeter operational condition. Finally, it can be concluded that the knowledge of leachate quality will be useful in planning and providing remediameterl measures of proper liner system in landfill design and leachate treatment.

References:

[1] Alamgir, M., Ahsan, A., McDonald, C.P. and Upreti, B.N. and Rafizul, I. M. (2005). Present Status of MSWM in Bangladesh, *Waste-The Social Context, Edmonton, Alberta*, Canada, pp.16:1-10.

[2] APHA (1998). *Standard Methods for Examination of Water and Wastewater*, 19^{th} edition, Prepared and published Jointly by American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation Publication (WEFP), Washington DC.

[3] Daniel, D. E. and Koerner, R. M. (1995). Waste Containment Facilities, Guidance for Construction Quality Assurance and Quality Control of Liner and Cover System, ASCE press, New York, N.Y, pp.13, 25-27.

[4] Davis, M.L. and Cornwell, D.A. (1998). Introduction to Environmental Engineering: *Third Edition*. New York, McFraw-Hill International, ISBN 0-07-115237-4.

[5] Diaz, L.F., Eggerth, L.L and Golueke, C.G. (1996). Solid Waste Management for Economically Developing Country, The world Bank, Washington DC, U.S.A, pp.318-327.

[6] Ehrig, H.J. (1989). *Leachate quality in Sanitary Landfilling: Process, Technology, and Envi. Impact*, T.H. Christensen, R. Cossu, and R. Stegman,Eds.; Academic Press, New York.

[7] Kelly, W.E. (1976). Groundwater Pollution Near a Landfill, ASCE, Journal of Environmental Engineering Division, Vol. 102, No. 6, pp 1189-1199.

[8] Krug, M. N. and Ham, R.K.(1995). Analysis of Long-Term Leachate Characteristics in Wisconsin Landfills, *Presented at the* 18^{th} *Int. Madison Waste Conf.*, Dept. of Engg. Professional Development, Madison.

[9] Rafizul, I. M., Alamgir, M., Kraft, E. and Haedrich, G. (2009). Characterization of Leachate Generated from MSW in Sanitary Landfill Lysimeter, Proc. of Sardinia 2009, Twelfth International Waste

Management and Landfill Symposium, 5-9 Oct., S. Margherita Di Pula, Cagliari, Italy.

[10] Rafizul, I.M. and Alamgir, M (2012). Characterization and Tropical Seasonal Variation of Leachate: Results from Landfill Lysimeter Studied, Journal of Waste Management, WM 8222 @ 2012 ELSEVIER Ltd.

[11] Robinson, H. and Gronow J. (1992). Groundwater Protection in the UK: Assessment of the Landfill Leachate Source-term, J. of the Institution of Water and Env. Management, V- 6, Pp 229-235.

[12] Roehl, K. E. 2007. Interna Report of External Experts of WasteSafe II. EU- Asia Pro Eco II Programme of European Commission, WasteSafe-II, Dept. of CE, KUET, 2007.

[13] Tubtimthai, O. (2003). Landfill Lysimeter Studies for Leachate Characterization and Top Cover Methane Oxidation, Thesis, Master of Science, Asian Institute of Technology, School of Environment, Resources and Development, Thailand, pp4-5.

[14] Visvanathan, C., Trankler, J., Kuruparan, P. and Xiaoning, Q. (2002). Influence of Landfill Operation and Waste Composition on Leachate Control: Lysimeter Experiments under Tropical Conditions. 2nd Asian Pacific Landfill Symposium, September 25-28, 2002, Seoul Korea, Session:4.

[15] WasteSafe (2005). Integrated Management and Safe Disposal of MSW in LDACs, A resent feasibility study under the Asia Pro Eco Programme of EC, Dept. of CE, KUET, Bangladesh, pp.139-181.