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Treatment of Leachate of Savar Solid Waste Landfill Site

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Abstract- Landfill leachate is complex waste water with considerable variation in both quality and quantity. The composition and concentration of pollutants are influenced by the types of waste deposited, hydro geological factors and more significant by the age of the landfill site. In general, leachate is highly contaminated with organic contaminants measured as chemical oxygen demand (COD), biochemical oxygen demand (BOD) and also with high ammonium nitrogen concentration. Aerobic biological processes have been found the most effective and reliable treatment option of landfill leachate for developing country like Bangladesh. Leachate containing high concentrations of organic and nitrogen compounds results serious environmental problems near the landfill site. This research was undertaken to investigate the performance of both chemical treatment by alum coagulation and biological process that is extended–aeration activated sludge process without sludge return and anaerobic treatment of Savar Landfill leachate containing high organic and nitrogen concentrations. The main part of the study was studied on the removal efficiency of BOD, COD and ammonia in each method and heavy metals removal were also studied in coagulation and flocculation method. It is observed that in extended aeration process BOD removal is around 80% at 6 days detention time and 94% at 15 days detention time. In the same treatment method experiment results reveal that 75% of ammonia removal is achieved in 6 days aeration period mainly due to air stripping process and in total 98% removal is achieved in 15 days aeration period. The optimum pH of alum coagulant for leachate treatment was 6.5. Also an effective dosage of alum is 1.4 g/L for the best efficiency of heavy metals and COD removal. The maximum amount of COD and heavy metals that could be removed by the alum was about 21 and 77-91% of the initial value, respectively. It is also found that anaerobic biological treatment alone cannot efficiently remove the COD content of leachate from the site. BOD/COD ratio was varies from 0.19 to 0.14 in anaerobic batch system for 20 and 41 days, respectively. This BOD/COD ratio means low biodegradability of treated leachate. Chlorine oxidation, coagulation with high alum dose and extended aeration also conducted after construction of treatment facility by Dhaka City Corporation at Savar landfill site. Only 20 to 41 % COD removed in chlorine oxidation and alum coagulation. The second extended aeration results show that the dilution is not essential to treat leachate. It was taken a few days initially to convert the facultative microorganisms into aerobic microorganisms.

Index Terms— Landfill leachate, COD, heavy metals, microorganisms.

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I. INTRODUCTION

One of the major consequences of rapid economic growth, urbanization, industrialization and population growth is the massive generation of solid waste at a rapid race all over the world. Although improvements are being made in reducing, reusing and recycling of waste, protecting the environment and human health continues to be a challenge. Municipal solid waste disposal in the landfill is the most common, cheep and easiest municipal solid waste management practice followed all over the world. However, landfill requires a close environmental engineering surveillance in its design and operation as it is likely to generate leachate which would potentially contaminate nearby groundwater and surface water. With the changing nature of domestic refuse composition over the years due to economic growth, the proportion of refuse available for decomposition has greatly increased and thus the organic strength of the leachate has increased, resulting in its greater potential to pollute water. So it is essential to focus on the environmental problems concerned with solid waste landfill disposal to protect the environment and prevent adverse health effects.

Leachate is formed when rain water contaminated as it passes through landfilled wastes. Generally, leachate contaminates are measured in terms of chemical oxygen demand (COD) and biological oxygen demand (BOD), halogenated hydrocarbons and heavy metals. The problem with leachate treatment is that leachate changes in terms of strength, biodegradability and toxicity as the wastes in the landfill age over time. Also, keep in mind that filled wastes may take up to a hundred years to stabilize; the chosen leachate treatment will be required to operate for a considerable period of time.

There is a lack of proper leachate collection and treatment in developing countries including Bangladesh. Most of solid waste of Dhaka City is disposed of at Savar the largest landfill site of Bangladesh. Previously the final disposal that is the landfill site was paid very little attention by Dhaka City Corporation. The landfill site was operated in a very simple way and there was no responsible organization to manage and control the landfill site before 2005. Waste was simply dumped and filled with out covering soil. There was no leachate collection and gas collection system. So the environmental pollution was increasing day by day due to the improper operation of landfill especially the leahate [1]. The situation has changed after the initiation of the project landfill improvement project taken by the Dhaka City Corporation. The landfill is transformed from open dumping into sanitary landfill and constructed a leachate collection and treatment facility.

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The aerated lagoon processes are just started and the treatment efficiency of the facility is not verified. So it might be very challenging for the authority to meet the required compliance in case of leachate effluent discharge quality in the rainy season through the current set up.

With respect to the environment, this situation should be well predicted and necessary steps in regard to treatment of leachate should be taken. Due to the financial situation and to the more stringent standards, leachate treatments are much more developed in industrialized countries [2]. High technology leachate treatment systems are often avoided because of high cost of construction and operation. Various biological treatment methods have been employed for the treatment of leachate from municipal solid waste landfill. Extended aeration systems, sequencing batch reactors and aerated lagoons can act as robust, stable and reliable means of treating leachate [3]. These treatment systems were found to be inefficient for leachate containing high strength organic substances and ammonia nitrogen. In addition, the organic loading and pH are significant in influencing the growth of nitrifying bacteria in nitrification process [4, 5, 6]. Due to high ammonia concentrations in the leachate, ammonia toxicity and sludge properties are affected in the biological treatment system. The high running costs of such systems have increased interest in the use of constructed wet land systems or an aerobic system where the methane produced can offset energy costs [7, 8]. There is much on-going research into leachate treatment systems aimed at reducing costs and increasing flexibility and improving treatment efficiency. The chemical methods include coagulation and precipitation and oxidation of the organics. The disadvantage of the coagulation and precipitation is that large amounts of sludge are produced which is difficult to manage. Looking into these aspects, landfill lechate treatment requires some economical efficient treatment technique to meet the required effluent standards.

The purpose of this study is to develop a suitable leachate treatment option that will help in construction of sanitary landfill disposal site as well as reducing the environmental pollution relater health risks and economic loss. The Savar is the only official dumping site in the Dhaka City and the largest landfill site in the country. Huge quantity of leachate is producing and collecting into the two aerated lagoons. But the efficiency and suitability of the present leachate treatment system will be analyzed.

The overall objectives of the research are to provide suitable treatment option for leachate of Savar Landfill of Dhaka City and to investigate the efficiencies of different treatment processes. The major objectives of the research are:

a) To collect and assess the quality of landfill leachate.
b) To investigate the efficiencies of different treatment processes.
c) To develop an efficient leachate treatment system.

II. EXPERIMENTAL PROGRAM

The present study on landfill leachate treatment comprises of three experimental stages, namely: collection of representatives samples, analysis to evaluate the quality of leachate and treatment of Savar landfill leachate by chemical and biological method.

A. Sampling Method

Proper standard collection of landfill leachate samples for analysis is of great importance. Representative combined samples were tested in the laboratory for the assessment of existing pollutants and treatment options. Combined samples were prepared by mixing equal volume of two samples collected from two points of each sampling locations. The collected samples were kept in standard box and were transported to laboratory and all possible efforts were made to minimize the time lag between collection and analysis so that no significant change may occur in the quality of the samples.

B. Frequency of Sampling

To study the leachate quality and treatment of Savar landfill, laboratory analysis were conducted for a couple of months of year 2009 to 2011 (October to December, 2009, July to December, 2010 and February to May, 2011). Again the samples were collected twice in a month.

C. Quality Assessment of Savar Landfill Leachate

An understanding of the nature of leachate is important in design and operation of collection process, treatment, disposal facilities and engineering management of environmental quality. To obtain the quality of Savar landfill leachate extensive laboratory investigations were carried out. Again relative data were also collected from different sources.

D. Treatment Procedure of Savar Landfill Leachate

In this study, different treatment methods such as extended aeration which is the basis for the present leachate treatment system of Savar landfill site, anaerobic biological treatment that is widely used in different countries and alum coagulation which is treated by various researchers especially for heavy metal removal as a pre or post treatment in the treatment were applied.

E. Extended Aeration without Sludge Return

The conventional extended aeration activated sludge process is essentially same as the aerated lagoon process which is comparatively economical for low income countries like Bangladesh. According to literature review it has been found that aerated lagoons achieve BOD5 removal greater than 90% at comparatively long retention times [9]. At the laboratory six sets of model tests have been carried out with leachate samples collected from the disposal channels to determine the extent of COD, BOD and ammonia removal. Collected leachates were aerated through air-diffusers under different dilution levels and environmental conditions.

F. Anaerobic Treatment of Savar Landfill Leachate

Anaerobic treatment is a biological process in which organic matter is degraded into a series of gaseous products, mainly CH_4, CO_2 and H_2 and its liquid effluent containing the most refractive compounds with significant presence of nitrogen, phosphorus and mineral compounds such as K, Ca and Mg. The main focus of this study was to investigate the potential of the application of anaerobic treatment system in BOD, COD and ammonia nitrogen (NH_3-N) removal of the fresh leachate. In this treatment process fresh leachate from Savar Sanitary landfill, Jatrabari, Dhaka was used.

The leachate were collected in 20 liter plastic bottles, transported to the laboratory and sieved using a 1.5 mm mesh to remove solid particles such as shell, fiber, small stones etc and then stored at 4°C before it was used for anaerobic treatment process. The anaerobic fermenter used for this study was a 1.5 liter plastic bottle covered with paper to prohibit light passing into the bottle. The selected fermenter was then filled with 1.25 liter fresh leachate and the treatment was carried out for 41 days because the changes were very significant. The bottle was sealed and only small tube was inserted in it to collect the sample and to facilitate the expulsion of gases. The pH of the anaerobic process was not controlled throughout the running of the entire treatment and at room temperature of 28±2 °C.

G. Chemical Treatment with Alum

The coagulation has been mainly investigated by using stabilized landfill leachate for removal of organic matter and solids. However, there is limited information on the efficiency of this process for heavy metal removal, especially when applied for the removal of pollutants from raw leachate. Therefore, the determination of the most appropriate coagulation dose, the examination of pH effect on removal capacity and the identification of optimum experimental conditions for the removal of organic matter and heavy metal are the another objectives of this paper.

III. RESULTS AND DISCUSSIONS

A. Physical and Chemical Properties of Savar Landfill Leachate

A detailed laboratory investigation was carried out to know the physical and chemical properties of Savar Landfill Leachate. The test results are presented in Table 1. From the Table 1 it is observed that, generally the concentration of different effluents in the Savar Landfill Leachate at August is higher than the March. Again for the both cases the the concentration of different effluents are higher than the Bangladesh Industrial Effluent Standards.

B. Extended Aeration without Sludge Return

For these test five samples having different dilution conditions and different BOD5 and COD concentration were tested. These samples were collected from two different locations of Savar Landfill site. The identification and chemical conditions of tested samples are presented in Table 2. From the Table 2 it is observed that sample S_1 and S_2 have high BOD_5 COD concentrations than the other samples. Figures 1a and 1b represent the variation in concentrations of BOD_5 and COD with time for different samples. From the Figures 1a and 1b, it is observed that the initial concentration of BOD_5 and COD of sample S_1 was 1260 mg/L and 6173mg/L, respectively. After five days the BOD_5 and COD of sample S_1 is reduced to 740 mg/L (about 41%) and 3630 mg/L (about 41%), respectively. Again the value of BOD_5 and COD of sample S_1 after ten days is 260 mg/L (about 79%) and 925 mg/L (about 85%), respectively.

Again, From the Figures 1a and 1b, it is observed that the initial concentration of BOD5 and COD of sample S_2 was 840 mg/L and 4115 mg/ L, respectively. After five days the BOD5 and COD of sample S_2 is reduced to 545 mg/L (about 35%) and 2670 mg/L (about 35%), respectively. Again the value of BOD_5 and COD of sample S_2 after ten days is 240 mg/L (about 71%) and 420 mg/L (about 90%), respectively.

In general relatively similar reduction tendency of BOD_5 and COD with time is also observed for samples S_3, S_4 and S_5, respectively.

However, if precisely look on the BOD_5 removal efficiency of all samples after five days the samples are in the order of $S_1>S_5>S_2>S_3/S_4$, respectively. After ten days the removal efficiency of all samples are in the order of $S_1>S_2>S_5>S_3>S_4$, respectively.

Again, the COD removal efficiency of all samples after five days the samples are in the order of $S_1>S_5>S_2>S_3/S_4$, respectively. After ten days the removal efficiency of all samples are in the order of $S_2/S_5>S_1>S_4>S_3$, respectively.

C. Anaerobic Treatment of Savar Landfill Leachate

Table 3 depicts the chemical concentration of fresh and treated leachate by anaerobic treatment at day 20 and day 41. From the Table 3 it is observed that the biodegradability rate of organic matter that is BOD/COD ratio of leachate inside the reactor is 0.55, 0.19 and 0.14 at day 1, day 20 and day 41, respectively. The ratio between BOD_5 and COD provides an indicator in the case of biological treatment. Biological decompression processes generally start quickly and proceed rapidly with BOD_5: COD ratios of 0.5 or greater. Ratios between 0.2 and 0.5 are amenable to biological treatment, but decomposition may proceed more slowly because degrading microorganisms need to become acclimated to the leachate. Again from the Table 3 it is observed that alkalinity changes from 1920 to 3100 mg $CaCO_3$/L at day 41 which indicates the increase of pH from 5.0 to 6.5 in the digestion. Initial ammonia nitrogen (NH3-N) increased from 485mg/L to 602 mg/L at 20 days and 675 mg/L at 41 days, respectively.

D. Chemical Treatment with Alum

In this treatment the effect of pH values and coagulation dosages are observed. The effect of pH values are presented in Table 4. From the Table 4 it is seen that the removal rate of COD and heavy metals from leachate is maximum at pH values of 6.5. The effect of coagulation dosages (alum) at optimum pH (6.5) on removal efficiencies of heavy metals and COD in leachate is shown in Figure 2. From the Figure 2 it is shown that the removal of COD and heavy metals increased with increasing concentration of coagulants. It is observed that the removal efficiency of heavy metals and COD increases from Alum doses of 350 mg/L to 1450 mg/L. After that the removal efficiency decreases with the increases of coagulation dosages. It is observed that the COD removal efficiency in alum coagulation process is lower than extended aeration processes but for the removal of heavy metals the alum coagulation is more efficient than other two extended aeration and anaerobic processes.

Table 1: Physical and Chemical Properties of Savar Landfill Leachate

Serial No	Parameter	Unit	Concentration	
			August	March
1	Temperature	°C	37~39	30~35
2	pH	Unit less	8.1-8.3	7.2~7.3
3	Colour	Pt-Co	7245~7268	6800~7700
4	Chloride	mg/L	1740~1765	3500~3900

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5	Iron	mg/L	10.3~12.1	31.7~41.2
6	Mn	mg/L	1.06~1.17	0.75~1.41
7	NO_3 -N	mg/L	55~62	70~80
8	TDS	mg/L	6400~6475	7125~7200
9	COD	mg/L	2395~2445	6300~6700
10	BOD_5	mg/L	1565~1630	4300~5574
11	PO_4	mg/L	16.85~17.11	14.3~33.1
12	EC	µS/cm	1150~1205	1710~1765
13	NH_3 -N	mg/L	575~600	1350~1430
14	NO_2 -N	mg/L	0.05~0.06	0.1~0.2
15	Cr	µg/L	4050~4100	1250~1450
16	Cd	mg/L	0.41~0.45	0.21~0.25
17	Pb	µg/L	1800~1845	930~940
18	Ni	ppm	0.031	0.041
19	Cu	mg/L	6.4~6.9	3.8~4.7
20	Hg	µg/L	Nil	Nil
21	Zn	mg/L	7.6~7.9	3.1~3.5

Table 2: Identification and chemical conditions of tested samples

Sample ID	Location	BOD_5 concentration (mg/L)	COD concentration (mg/L)	Dilution (%)
S_1	Near Hospital waste Management Facility Drain	1680	8230	25
S_2				50
S_3	North-West Drain	200	2220	25
S_4				50
S_5	Mixed of above two locations	950	5026	50

Table 3: Leachate characteristics in batch process for 20 and 41 days

Parameters	Raw sample/Initial	After 20 days	After 41 days
pH	5.0	5.8	6.5
Temperature (°C)	28±2	28±2	28±2
COD (mg/L)	4480	3134 (43%)	3052 (44%)
BOD (mg/L)	3005	578 (80%)	430 (85%)
BOD/COD	0.55	0.19	0.14
NH_3-N	485	602	675
Alkalinity (as mg $CaCO_3$/L)	1920	2510	3100

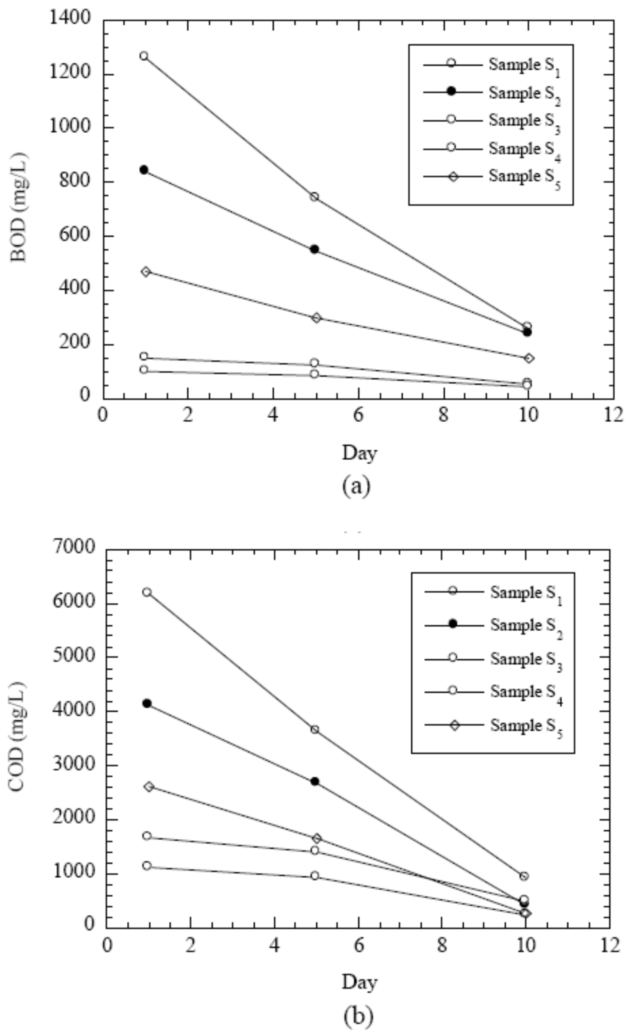

Figure 1: (a) Concentration of BOD with time and (b) Concentration of COD with time

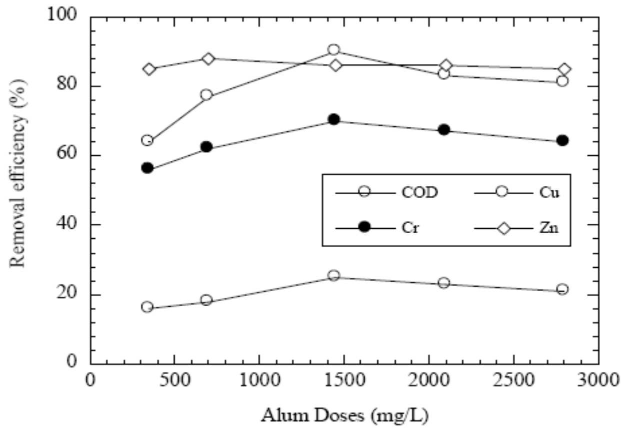

Figure 2: The effect of coagulation dosages (alum) at optimum pH (6.5) on removal efficiencies of heavy metals and COD in leachate.

Table 4: Effect of pH values on coagulation efficiencies and removal of heavy metals

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pH Value	4.0	5.0	6.0	6.5	7.0	8.0
Initial COD (mg/L)	3320	3320	3320	3320	3320	3320
COD after Coagulation (mg/L)	2990	2920	2820	2715	2780	2825
Initial Cd (mg/L)	0.417	0.417	0.417	0.417	0.417	0.417
Cd after Coagulation (mg/L)	0.242	0.233	0.183	0.092	0.125	0.133
Initial Cr (μg/L)	4125	4125	4125	4125	4125	4125
Cr after Coagulation (μg/L)	1733	1690	908	825	1568	1733
Initial Cu (mg/L)	6.885	6.885	6.885	6.885	6.885	6.885
Cu after Coagulation (mg/L)	3.990	3.860	1.930	1.380	2.550	2.890
Initial Zn (mg/L)	7.779	7.779	7.779	7.779	7.779	7.779
Zn after Coagulation (mg/L)	4.510	3.730	2.330	1.400	2.340	2.490
Initial Ni (ppm)	0.0308	0.0308	0.0308	0.0308	0.0308	0.0308
Ni after Coagulation (ppm)	0.0180	0.0175	0.0115	0.0110	0.0112	0.0129

IV. CONCLUSION

Several techniques to treat Savar Landfill Leachate were studied in the laboratory. In case of of extended aeration process experiment results shows that about 80% and 94% of BOD removal can be achieved at a detention time of 6 days and 15 days, respectively. Again 75% and 98% of ammonia removal is achieved in 6 days and 15 days, respectively.

The treatment of fresh leachate from Savar Landfill site by coagulation and flocculation process shows that the optimum pH value of alum coagulation for leachate treatment is 6.5. Also an effective dosage of alum is 1.4g/L for the best efficiency of heavy metals and COD removal. Again, the maximum amount of COD and heavy metal removal by alum is about 21% and 77-91%, respectively. Moreover large amount of sludge are generated in this process. So in terms of COD removal efficiencies and huge sludge handling problem this method is suitable for treating Savar landfill leachate. It is also observed that anaerobic biological treatment alone cannot efficiently remove the COD content of leachate from the site.

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