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Municipal Solid Waste Stabilisation by Leachate Recirculation: A case study of Ambala City

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ABSTRACT

The purpose of this study is to determine the impact of leachate recirculation on stabilisation of municipal solid wastes. The study was carried out by using two lab- scale landfill bioreactors containing approximately 10 kg of waste each, in order to follow waste degradation over 16 weeks of time period. The main difference between anaerobic recirculated and without recirculation bioreactors options is determined in leachate quality. Leachate quality is regularly measured by the means of pH, electrical conductivity, calcium, magnesium, total kjeldahl nitrogen, phosphate and chemical oxygen demand (COD). It has been observed that leachate recirculation is more effective on anaerobic degradation of solid waste than non-recirculated degradation. The leachate recirculated bioreactor appears to be the more effective option in the removal of COD by 89.93% and stabilisation of pH at 7.5. After 16 weeks of anaerobic degradation, waste stabilization seemed to have reached for the recirculated bioreactor. Therefore, further studies required to determine the optimum operational conditions for leachate recirculation rates, also with the operational costs of recirculation for solid waste stabilisation.

Keywords: Municipal solid waste, leachate, leachate recirculation, landfill bioreactor, cow dung.

1. Introduction

In most countries, sanitary landfill is the most widespread and economical method for disposal of both municipal solid wastes (MSW) and industrial waste. In spite of many advantages, generation of heavily polluted leachates, presenting significant variations in both volumetric flow and chemical composition, constitutes a major drawback (Renou et al., 2008). Moreover, landfill leachate normally contains high concentrations of organic matter, nutrients, pathogens and heavy metals, which, if not properly collected and treated, can cause serious pollution of surface and groundwater sources. Landfill leachate treatment has been given significant attention in recent years, especially for municipal areas (Ahn et al., 2002; Bohdziewicz et al., 2001; Geenens et al., 2001). Proper treatment of the leachate has therefore been a challenging task (Neczaj et al., 2005). Sometimes the presence of heavy metals at high concentrations in landfill leachate usually causes toxic effects to microbes, making it difficult to treat biologically (Sawaittayothin and Polprasert, 2007). For treatment of leachate new low cost technology/low cost solutions for small scale treatment of these leachate are desired in order to reduce their organic loads (Castillo et al, 2007).

The recognition of landfill leachate impact on environment has forced researchers to find alternatives technology for pollution control. Further, the difficulties in managing large volume of leachate, in practise, no full scale experiment has yet demonstrated. Research on leachate recirculation began with the laboratory and lysimeter-scale simulations, which emphasized leachate treatment (Li et al., 1999). The advantages of leachate recirculation have been demonstrated by many researchers that performed numerous lysimeters and field tests (Chan et al., 2002; Erses and Onay 2003; San and Onay, 2001).

This research work was carried out to investigate the effects of leachate recirculation on stabilization of the municipal solid waste (MSW) anaerobically.

2. Materials and method

For the present study the municipal solid waste (MSW) samples were collected form the various dumping sites of Ambala city (Haryana) and analyzed in the laboratory. Five random samples were collected from the MSW dumping site so as to have a fair uniform composition. 5 Kg of properly mixed samples were weighed and segregated for the analysis physico-chemical composition. All the samples were mixed properly in laboratory and air dried. The air dried sample was ground and passed through < 2mm pore size sieve to get uniform size.

2.1 Lab-Scale simulated landfill bioreactor

Bioreactors were designed in order to simulate the municipal solid waste landfill under controlled anaerobic conditions. The schematic configuration of the reactor is shown in Figure 1.

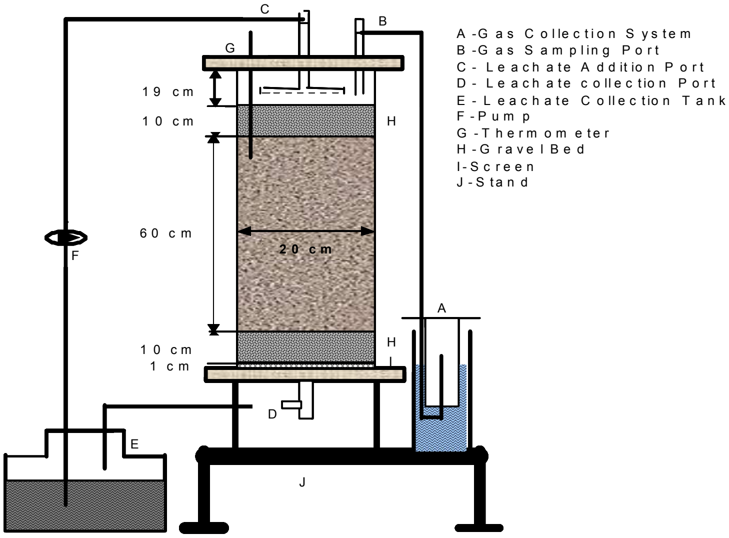

Figure 1: Schematic diagram of lab scale simulated landfill bioreactor

The reactors used for this work are cylindrical in shape, having 20 cm diameter and 100 cm height. The bioreactors were operated in batch mode at normal room temperature. The leachate was collected at the bottom section of the solid waste reactor and the effluent was recycled to the top of the reactor using a peristaltic pump.

2.2 Experimental set-up for study

There were two identical reactors, loaded with 10 kg of unshraded solid waste each. A 10 cm thick layer of gravel was placed at the bottom of each bioreactor to simulate a leachate collection system, and to prevent clogging of the leachate withdrawal outlets. Solid waste was loaded in layers and compacted using a hammer. A second gravel layer was placed on top of the waste to simulate informedate cover and upper drainage layer and further to provide even distribution of the recirculated leachate. The nominal size of the gravel used for both filter layers range from 16 to 40 mm. Finally the bioreactor cell covers were placed on top of each cell and whole unit was sealed using construction type sealant.

In the beginning reactors were fed by tap water in the rate of 4 ml/min until the amount of leachate collected become equal to amount added the previous day. The first bioreactor (**R1**: without leachate recirculation) was compacted with 100% MSW and second bioreactor (**R2**: with leachate recirculation) was compacted with 25% of cow dung + 75% of MSW by weight. Cow dung was added to facilitate the enzymatic hydrolysis or extracellular depolymerisation of polymers such as carbohydrate, fat and protein. The leachate recirculated to the reactor at the feeding rate of 4ml/min.

2.3 Analytical procedures

From each reactor 100 ml of sample was collected in every week and used for the determination of physico-chemical parameters. The following parameters were analyzed from each sample: pH, EC, Ca^{+2}, Mg^{+2}, TKN, PO_4^{3-} and COD.

All the chemicals used were of GR/AR grade and double distilled water was used throughout the experiment. All the analysis were done in accordance with the analytical procedures given in standard methods (Andrew et al, 2005). pH was determined immediately after sampling to avoid any change due to the CO_2 evolution using a pH meter (pH Tutor, Mfg. by: Eutech Instruments). All experiments were carried out in triplicate and the mean values are reported.

3. Results and discussion

The present research work was carried out to study the effect of leachate recirculation on solid waste stabilization as well as changes in leachate characteristics in a lab scale anaerobic leachate recirculation reactor. The leachate samples were collected weekly to analyze pH, EC, Ca^{+2}, Mg^{+2}, PO_4^{3-}, TKN and COD. The results obtained and the overall variations observed in different parameters of the leachate samples are shown in Figure 2-8.

3.1 Composition of leachate and municipal solid waste (MSW)

The chemical characteristics of a typical leachate are presented in Table 1. The physico-chemical characteristics of municipal solid waste collected for the present study are shown in Table 2 and 3. The amount of food waste was the highest in general MSW. Soil has the lowest percentage in MSW. It shows that most of the waste dumped at solid waste dumping site consists of kitchen waste.

Table 1: Typical leachate composition (After Bhushan, 2004).

Parameters	mg/L
BOD	10, 000
COD	60, 000
TSS	500
Ammonia Nitrogen	2, 500
Total Phosphorous	30
Copper	15
Zinc	130
Iron	400
Cadmium	<0.1
Manganese	14
Arsenic	<0.01
Mercury	<0.01
Sodium	2, 200
Potassium	1, 400
Calcium	1, 000
Magnesium	250
Chloride	6, 000
Cyanide	<0.1

Table 2: Composition of municipal solid waste.

Sr. No	Category of solid waste	Percentage (%)
1	Food waste	47.65
2	Paper	19.82
3	Wood	12.25
4	Textile	11.18
5	Leather	4.4
6	Yard waste	2.5
7	Soil	2.2

Table 3: Characteristics of municipal solid waste.

Sr. No	Parameters	Values
1	Moisture content	48.68 %
2	TOC	0.49 %
3	Calcium	76.2 ppm
4	Magnesium	32.8 ppm
5	Sodium	14.5 ppm
6	Potassium	9.7 ppm
7	Phosphate	0.97 ppm
8	Nitrogen	16.5 ppm

3.2 pH and Conductivity

The variation of pH profile over time is provided in Figure 2. The first two weeks of the testing represents the initial adjustment and transition of MSW degradation from aerobic to anaerobic phases. During these two weeks pH levels were approximately 6.0, or on the acidic side of the pH scale. The observed pH values of leachate samples ranged from 6.1 to 5.9 in reactor R1 and 6.2 to 5.8 in reactor R2.

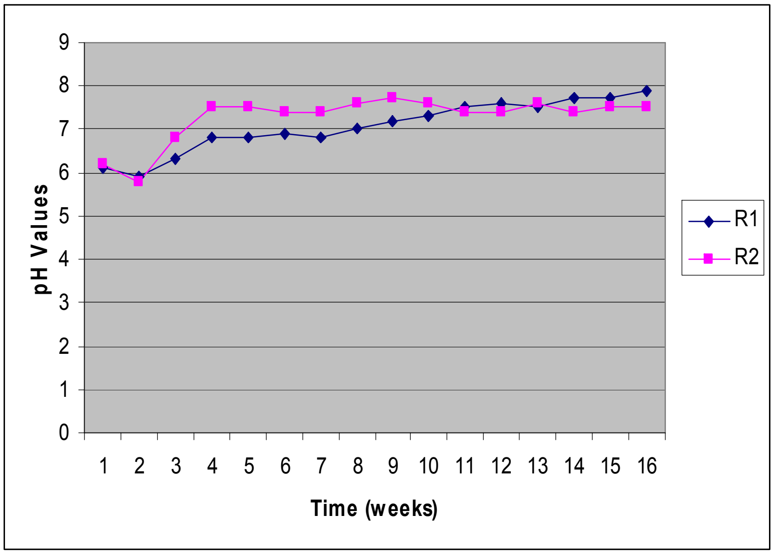

Figure 2: Variation of pH in reactor R1 and R2

The initial acidic pH in the anaerobic bioreactor decreased and reached to 5.9 on 2nd week and after 4th week the pH values varies in between 6.8 to 7.9 in reactor R1 and 7.4 to 7.7 in reactor R2. This increase in pH value is due to onset of methanogenic activity as a result increase in methane gas production and decrease in hydrogen, carbon dioxide and volatile fatty acid production (Murphy et al., 1995). A decrease in CO_2 leads to decrease in carbonic acid (H_2CO_3) and bicarbonate ion concentrations (HCO^-_3) consuming H^+ ions (Kim, 2005).

The conductivity of a leachate reflects its total concentration of ionic solutes and is a measure of the solution's ability to convey an electric current. In both the reactors, the change in leachate conductivity with time followed a similar trend as shown in Figure 3.

The initial values of EC are 39576 and 36874 µS/cm in reactors R1 and R2 respectively. The maximum value of EC was 39786 µS/cm in 3rd week and then started to decrease in reactor R1 whereas in Reactor R2 maximum value was 36936 µS/cm in 2nd week and then started to decrease. At the end of 16th week the minimum values were found to be 24643 µS/cm and 18367 µS/cm in reactor R1 and R2 respectively. This is because metals tend to form hydroxides or undergo sulfidation in the anaerobic phase and the majority of these compounds are not readily soluble (Rich et al., 2008).

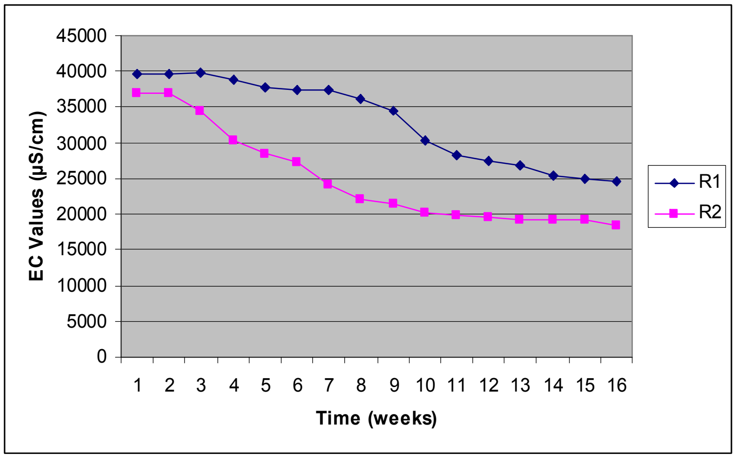

Figure 3: Variation of electrical conductivity (EC) in reactor R1 and R2

3.3 Calcium (Ca^{+2}) and Magnesium (Mg^{+2})

The Ca^{+2} and Mg^{+2} concentrations of both the reactors are shown in **Fig 4 & 5**. The minimum values for calcium were found to be 510.2 mg/L and 625.5mg/L at the end of 16th week in the reactor R1 and R2 respectively. The maximum values of calcium in reactor R1 was found to be 745.5 mg/L at the end of 4th week and in 3rd week 850.4 mg/L in reactor R2. After 4th and 3rd week in reactor R1 and R2 the concentration of calcium starts to decrease. This is due to formation of precipitant like $CaCO_3$ (Erses et al., 2008) and uptake of calcium by the microbes whose concentration started to increase.

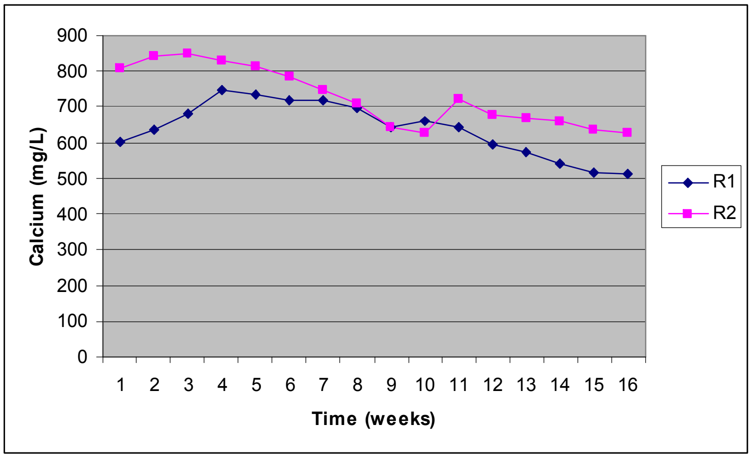

Figure 4: Variation of calcium in reactor R1 and R2

On the other hand the magnesium values varied from 325.5 to 580.2 mg/L in case of reactor R1 and 390.3 to 690 mg/L in case of reactor R2. In the reactor R1 & R2 the maximum concentration of magnesium was obtained in 7th & 4th week. After reaching the maximum value the concentration of magnesium started to decrease. The decrease in concentration is due to the formation of precipitant like Mg $(OH)_2$ (Erses and Onay, 2003). The trend shows more or less similar as given for Calcium.

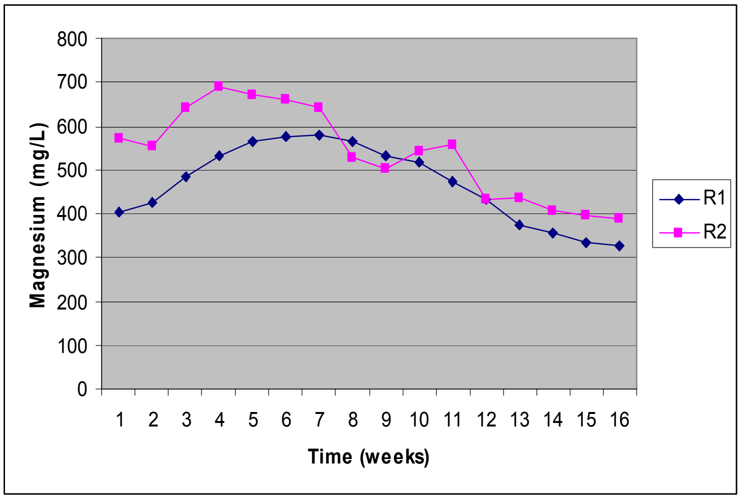

Figure 5: Variation of magnesium in reactor R1 and R2

3.4 Total Kjeldahl Nitrogen (TKN) and Phosphate (PO_4^{3-})

Nitrogen which has potential to pollute water and soil is another major constituent in the leachate. The TKN values varied from 311.5 to 757 mg/L and 823.2 to 874 mg/L in reactor R1 and R2 respectively. The TKN value in leachate in reactor R1 increased upto 757 mg/L by the 5th week and then started to decrease whereas in reactor R2 the TKN value of leachate increased upto 874 mg/l in 4th week and then remain almost constant throughout experiment **(Figure 6).**

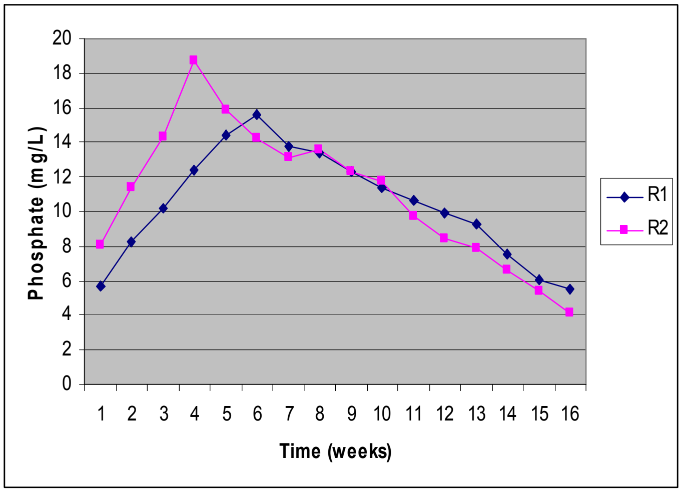

Figure 6: Variation of phosphate in reactor R1 and R2

The recirculation practice in the reactor R2 reintroduces ammonia to the system, keeping its value almost constant throughout experiment. The increase in removal efficiency in reactor R1 is due to bacterial synthesis and conversion of organic nitrogen compounds to NH_4-N by nitrification (Metcalf and Eddy, 1991).

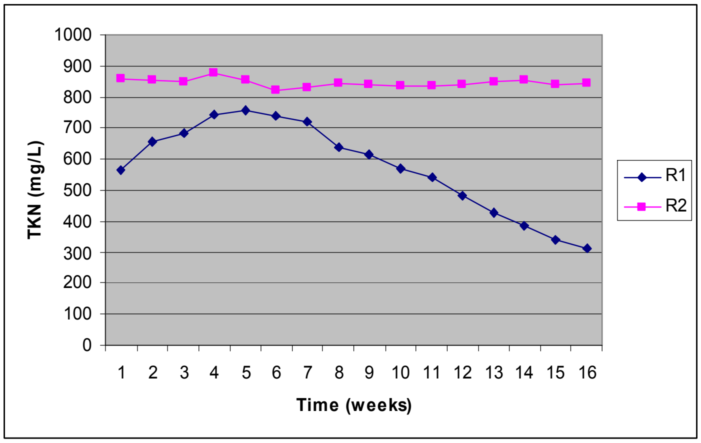

Figure 7: Variation of total kjeldahl nitrogen (TKN) in reactor R1 and R2

In the 6th and 4th week the maximum concentration of phosphate was found to be 15.6 mg/L and 18.7 mg/L in reactor R1 & R2 respectively. At the end of the experiment the phosphate concentration was found to be decreased and was 5.5 mg/L in case of reactor R1 and 4.1 mg/L in reactor R2 (Figure 7). The decline in phosphate concentration may have been the results of phosphate assimilation by microorganisms in the reactors.

3.5 Chemical oxygen demand (COD)

The initial COD concentration in the leachate sample collected from reactor R1 and reactor R2 were 5333 and 6933 mg/L respectively. The COD value in leachate in reactor R1 increased up to 10560 mg/L on the 6th week and then started to decrease but in reactor R2 the COD value of leachate increased upto 9600 mg/L by the 4th week and then started to decrease (Figure 8).

The reason for this decrease in COD level may be the quick degradation of the solid wastes in the lab scale anaerobic MSW reactor (Sponza and Agdag, 2004). The maximum value of COD reaches on 4th week in reactor R2 as compared to reactor R1 in which maximum value reaches on 6th week. This may be because of faster degradation of waste by microbes which were present in cow dung of reactor R2. Percentage removal of COD in reactor R1 and R2 were observed 80.3 and 89.93 % respectively. High COD removal in reactor R2 may be due to cow dung addition which may result in easy and well developed microbial culture.

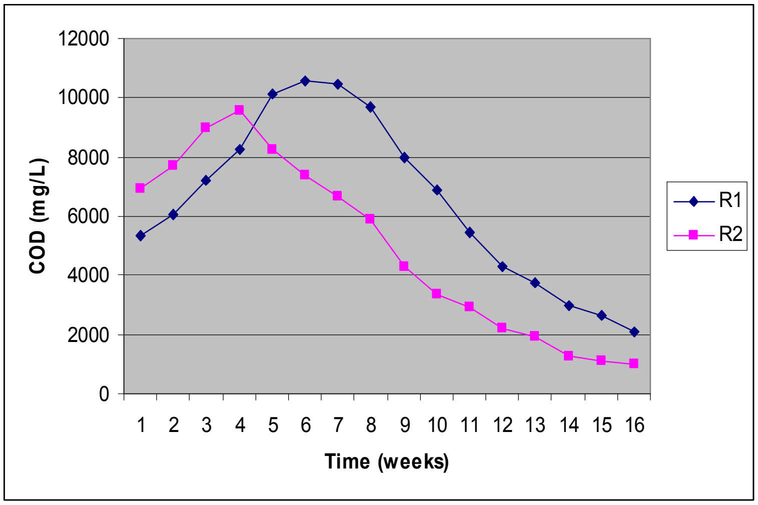

Figure 8: Variation of chemical oxygen demand (COD) in reactor R1 and R2

4. Conclusion

The leachate recirculation is a feasible way for in situ leachate treatment. The work shows that landfill leachate management with leachate recirculation is a promising and challenging strategy. The daily recirculation strategy has a positive effect related to COD removal, pH stabilization and other parameters. Maximum COD removal observed was 80.30% in reactor R1 and 89.93% in reactor R2. Cow dung addition will generate methane (CH_4) results in faster and more stabilization of solid waste as COD removal in case of reactor R2 was reported higher. All other parameters were also reported to be decreased with respect to time. The results of the present study reveals that the feasibility of leachate recirculation is reducing the overall leachate loading for treatment and in enhancing the degradation rate of waste. Therefore, further studies required to determine the optimum operational conditions for leachate recirculation rates, also with the operational costs of recirculation for solid waste stabilisation.

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