Nature Environment and Pollution Technology
An International Quarterly Scientific Journal | ISSN: 0972-6268 | Vol. 14 | No. 4 | pp. 919-922 | 2015

Original Research Paper

Anaerobic Treatment of MSW Using Leachate Recirculation Bioreactor: A Case Study of Rohtak City

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 11-01-2015
Accepted: 03-03-2015

Key Words:
Solid waste
Bioreactor
Landfill leachate
Leachate recirculation

ABSTRACT

Leachate recirculation is a leachate management technique and an option for faster stabilization of MSW. The objective of this research is to highlight the effects of leachate recirculation on waste stabilization in simulated bioreactor. The study was conducted in a laboratory in a cylindrical shaped bioreactor loaded with MSW waste maintained under controlled anaerobic condition. The leachate quality was regularly measured and operating parameters like pH, VFA, alkalinity, etc. were found in the optimum range of anaerobic degradation. The leachate recirculated bioreactor is an effective option for MSW management, as COD removal observed was 96% during the study period. These observations indicate that the leachate recirculation technique is a viable approach to treat landfill leachate and stabilize the MSW.

INTRODUCTION

The per capita generation of Municipal Solid Waste (MSW) has increased tremendously with population growth and improved lifestyle and social status of the population in urban centres. The amount of MSW generated per capita is estimated to increase at a rate of 1-1.33% annually (Pappu et al. 2007, Shekdar 1999, Bhide & Shekdar 1998). The quantity of municipal solid waste in developing countries consistently has been rising over the years (Kansal 2002). As more land is needed for the ultimate disposal of these solid wastes, issues related to disposal have become highly challenging (Idris et al. 2004). The Ministry of Urban Affairs, Govt. of India, estimates approximately 100,000 metric tonnes of solid waste generated everyday and of which 90% is dumped in the open place. Improper management of solid waste has been reported by several researchers in different cities of developing countries (Berkun et al. 2005, Sharholy et al. 2008, Imam et al. 2008, Chung et al. 2008). The method of MSW disposal in most of the urban and rural areas of developing countries is open dumping. This unscientific disposal practice causes public health and creates environmental problems (Khajuria et al. 2008, Gupta et al. 2007, Rathi et al. 2006, Sharholy et al. 2005, Ray et al. 2005, Jha et al. 2003, Singh et al. 1998). Leachate generation is an inevitable consequence of the deposition of solid waste in sanitary landfills and open dump. Sanitary landfill leachate is highly complex polluted wastewater containing high amount of organic and inorganic contaminants.

Proper treatment of the leachate is also a challenging task (Neczaj et al. 2005). 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). The strength of organic and inorganic contaminants appears to be inversely proportional to landfill age. Recirculation of leachate as an operational modification to conventional landfills has gained popularity in recent times (Syamsiah et al. 2013).

MATERIALS AND METHODS

A 28 kg of MSW was collected from dumping sites of Rohtak city in Haryana. About 5kg properly mixed sample was taken and sorted for determination of composition. 2kg of waste was oven dried at 105°C for moisture measurement and this waste was used for determination of its physico-chemical properties as per the methods of Ryan et al. (2001).

A cylindrical shaped bioreactor having 20 cm diameter and 100 cm height was used for the study. During the reactor set up, a 10 cm thick layer of 32-40 mm gravels was placed at the bottom, followed by a second 10 cm layer of 16-32 mm gravels, to simulate a leachate collection system. After placing the gravel layers, 15 kg of shredded MSW was added to the reactor and compacted. A final 10 cm layer of gravels size 16 to 40 mm was placed on top of the waste to simulate the upper drainage for even distribution of the recirculated leachate. The reactor and leachate collection container was sealed air tight. Water was added to MSW to increase the moisture content of the solid waste. More water was added on daily basis to MSW to generate 20 L of leachate. The leachate collected, from the bottom in a separate container, was recirculated back to the reactor at a flow rate of 20 mL/min with the help of peristaltic pump. The 20 mL and 50 mL leachate samples were collected on daily and weekly basis for physico-chemical analysis (APHA 2005). Leachate volume was made up by adding distilled water equal to the volume of leachate samples collected and accordingly a dilution factor was used in the calculation. All chemical analysis was carried out in triplicate to ensure the validity of the results.

Table 1: Composition of municipal solid waste of Rohtak.

Sr. No	Category of solid waste	Percentage (%)
1.	Kitchen waste	57
2.	Textile	14
3.	Leather	5.5
4.	Paper	12.5
5.	Plastic	6
6.	Metal	1
7.	Soil	4

Table 2: Characteristics of municipal solid waste of Rohtak.

Sr. No	Parameters	Values
3	Moisture Content (%)	51.9 %
1	pH	6.6
2	EC (mS/cm)	6.8 mS
4	Alkalinity	2.2 mg/g
5	Chloride	4.4 mg/g
6	Calcium carbonate	425 mg/g
7	Sulphate	4.92 mg/g

RESULTS AND DISCUSSION

The MSW was segregated to determine its composition and the result is given in Table 1. It comprises of kitchen waste, paper, plastic, leather, textile, metal, and soil. The kitchen waste was highest and the metal was lowest in MSW. Major constituents of MSW are organics which are biologically degradable in bioreactor landfill.

The physico-chemical characteristics of MSW used in leachate recirculation study are given in Table 2. Results show that MSW is slightly acidic in nature and has high moisture content (51.9%). The present research work was carried out to study the effect of leachate recirculation on solid waste stabilization as well as the changes in leachate characteristics in a lab scale anaerobic leachate recirculation reactor. The leachate samples were collected and analysed for various physico-chemical properties. The results of the leachate recirculation study are given in Table 3 and discussed below:

pH: pH varied from 5.3 to 7.5 during the study period. Initially, acidic pH of the leachate indicate the accumulation of volatile fatty acids in the early stage of bioreactor operations. After 4th week it started to increase and stabilized between 7.2 and 7.5 after 15^{th} week of leachate recirculation. Chian & Dewalle (1976) have reported that the pH of leachate increases with time due to decrease in the concentration of VFA in the system and the results are further supported by Warith (2002). The optimum pH range for anaerobic degradation is 6.5 to 8 (Shefali 2002). The hydrogen, carbon dioxide and volatile fatty acid concentration decreases, leading to increase in pH (Murphy et al. 1995).

Electrical conductivity: The electrical conductivity (EC) expresses the solution ability to conduct current and indirectly reflect the concentration of ionic solutes (TDS). The conductivity of leachate decreased from 7.95 mS/cm to 4.22 mS/cm in the reactors. High EC in leachate may be mainly due to the presence of inorganic salts which in turn contributes to high TDS (Esakku et al. 2003). During the study period a decrease in TDS was observed with time. This may be because of the metals that tend to form hydroxide or undergo sulphidation in anaerobic degradation (Rich et al. 2008).

Total dissolved solids (TDS), total suspended solids (TSS) and volatile suspended solids (VSS): The total dissolved solids (TDS) comprises mainly of inorganic salts and dissolved organics (Bhalla et al. 2012). The TDS decreased from 35800 mg/L to 7200 mg/L during the study period. An initial decrease followed by an increase and then again decrease in the concentration of TDS, was observed during the study period. Shoeybi et al. (2012) also observed this type of trend of TDS variation. Increase in TDS may be due hydrolysis of complex organics, whereas decrease in TDS may be due to its utilization by microbes during anaerobic degradation.

The total suspended solids (TSS) represent the suspended solids and larger particles which take longer time to decompose and disintegrate (Sartaj et al. 2010). The TSS decreased from 8250 mg/L to 3200 mg/L (61.2% reduction). After initial increase a continuous decrease in TSS was observed during the study period. The volatile suspended solids (VSS) decreased from 3820 mg/L to 1420 mg/L (62.8% reduction) during the study period. After initial increase a continuous decrease in VSS was observed during the study period.

Total Kjeldahl nitrogen (TKN): The TKN decreased from 1340 mg/L to 252 mg/L in the bioreactor. A gradual decrease in TKN was observed with time and at the end of the study period, 81.1% reduction in TKN was observed. De-

Table 3: Leachate quality of MSW of Rohtak during the study period.

Week	pH	EC	TDS	TSS	VSS	SO_4^{2-}	TKN	VFA	Alk.	VFA/ ALK	COD
1	5.3	7.84	35000	7000	1540	828	1120	5280	7050	0.75	14280
2	5.5	7.95	31000	8200	1740	902	1050	10200	12900	0.79	11780
3	5.8	7.65	32400	7290	1680	885	1260	9080	11000	0.83	10860
4	5.9	7.57	34000	8120	1940	940	1340	7720	10460	0.74	13000
5	6.5	7.45	31200	8250	2050	865	1100	8680	9300	0.93	12200
6	6.6	6.95	29210	7350	2250	48	1050	7220	8500	0.85	8500
7	6.7	6.83	27130	7510	2680	802	1260	7080	7600	0.93	7000
8	6.6	6.72	26400	6980	2840	765	952	6750	7200	0.94	5500
9	6.7	6.54	29800	6240	3060	747	1092	6280	6950	0.90	4933
10	6.8	6.32	35800	7210	3640	787	840	6580	6800	0.97	2640
11	6.9	6.04	31200	6900	3820	825	980	5680	6450	0.88	2266
12	6.7	5.98	29600	5420	3640	798	1036	4880	6150	0.79	1900
13	6.9	5.68	22460	5010	3320	745	896	5020	5700	0.88	1750
14	6.8	5.79	19800	4840	2980	725	812	4900	5500	0.89	1900
15	7.3	5.45	17800	4500	2720	740	700	4880	5300	0.92	1540
16	7.5	5.25	14500	4320	2440	705	630	4520	5100	0.89	1250
17	7.3	5.12	11200	4000	2220	685	560	4500	5250	0.86	1150
18	7.4	4.79	10200	4410	2040	702	448	4220	4950	0.85	1040
19	7.2	4.62	9000	4220	1920	682	406	3980	4800	0.83	800
20	7.3	4.52	8200	3980	1800	652	350	3640	4420	0.82	740
21	7.4	4.62	7950	3720	1660	634	280	3420	4120	0.83	620
22	7.5	4.22	7200	3200	1420	620	252	3220	3750	0.86	560

Note: All parameters are measured in mg/L except pH and EC (mS/cm).

crease in nitrogen may be due to bacterial synthesis and conversion of organic compounds to NH_4N (Metcalf & Eddy 1991). This is because ammonia is produced as a by-product of anaerobic digestion, principally from the mineralization of organic nitrogen during the deamination of proteins and amino acids (Shoeybi et al. 2012).

Sulphate: The sulphate content of leachate mainly depends on the decomposition of the organic matter present in the solid waste. It is expected to decrease with refuse age (Bhalla et al. 2012). The sulphate decreased from 940 mg/L to 620 mg/L during the study period. The SO_4^{-2} concentration has shown a great variation during the study period but in overall it showed a decreasing trend. The decrease is caused by the reduction of sulphate to sulphide, coincident with the initiation of anaerobic condition in the landfill (Shivakumar et al. 2004). Sulphate concentration in leachate can also be used as an indicator of waste stabilization within landfill (Bhalla et al. 2012).

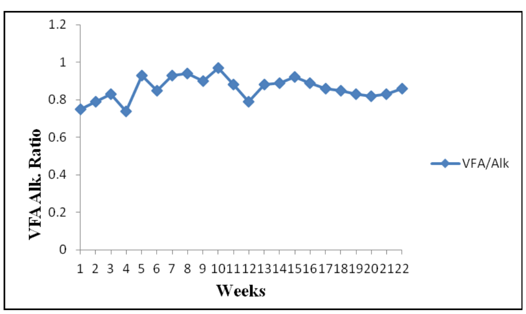

Fig. 1: VFA alkalinity ratio of leachate of Rohtak MSW.

Volatile fatty acids (VFA)/alkalinity: The organic fraction of the municipal solid wastes hydrolysed to intermediate organics and volatile fatty acids. The initial VFA concentration in the reactor was 5280 mg/L. However, it subsequently increased to about 10200 mg/L. High VFA concentrations in leachate may be due to the predominance of acidic phase (Sponza et al. 2004). At the end of the study, VFA was reduced to 3220 mg/L. A 68.4% reduction in VFA was observed during the study period. Gradual decrease in VFA concentration may be due to its utilization as a substrate to biogas by methanogenic bacteria. This decrease in VFA corresponded to the removal of COD (Tajarudin et al. 2007).

Alkalinity or buffer capacity is necessary to maintain a stable pH in the digester for optimal biological activity. The degradation of protein by anaerobic treatment, results in generation of alkalinity due to the reaction of ammonia with CO_2 and water (Gohil & George 2006). The alkalinity ranged from 12900 mg/L to 3750 mg/L during the study period. After transition to methanogenic conditions, pH was increased and total alkalinity tend to increase because methanogens utilized the available VFA as substrate (Eres et al. 2008).

The VFA alkalinity ratio varied from 0.97 to 0.74 (Fig. 1). Initially, the VFA alkalinity ratio was high but gradually it reached to the optimum value of an anaerobic treatment condition. The ratio of more than 0.8 causes unbalanced condition in the bioreactor (Vlissidis & Zauboulis 1993).

Chemical oxygen demand (COD): Chemical oxygen demand (COD) was measured as an indicator of leachate organic strength. The leachate COD decreased from 14280 mg/L to 560 mg/L in the bioreactor. Except initial variation, the COD gradually decreased with time. The initial increase in COD may be due to the rapid release and hydrolysis of complex organics from solid waste to the leachate and also due to the accumulation of organic acids (Erses et al. 2008). After the onset of methanogenic conditions, the COD concentration began to decrease. At the end of the study period, bioreactor COD was 560mg/L and maximum COD reduction was 96%. The decrease in COD may be due to the anaerobic decomposition of simple compounds i.e., VFA into CH_4, CO_2 and H_2S etc. The reason for this decrease in COD level may be the quick degradation of the solid wastes in the lab scale anaerobic MSW bioreactor (Sponza & Agdag 2004).

CONCLUSION

Bioreactor operations of leachate recirculation were found to bring about an extensive reduction in organic loads which were very high initially. The pollution indicator COD was reduced by 96%. Still, it is a time consuming process, but for the disposal of leachate on site, it is a good technique if applied in a skilled manner.

ACKNOWLEDGEMENT

This research is based upon work supported by University Grant Commission under Major Research Project Grant No. 39-337/2010(SR).

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