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Aerobic Landfill Bioreactor: Modelling and Analysis

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Abstract—*Landfill bioreactor was operated under aerobic conditions. Reactor was filled with 35 kg of shredded solid waste. Aerobic conditions in the reactor were developed by using an air pump. In this study effect of the leachate recirculation on aerobic degradation of municipal solid waste is determined. Settlement of the waste is regularly monitored. Results shows the acidogenic phase is still going on because of the low pH values less than 7. BOD/COD ratio is greater than 3 which shows that the waste is young. The waste settlement occurred rapidly in the starting of the experiment this is due to physical and mechanical process, called as primary settlement. After few days of experiment rate of settlement decreases this is due to chemical and biological process, called as secondary settlement.*

Keywords*: Leachate, Landfill bioreactor, Aerobic, Settlement, Acidogenic phase.*

1. INTRODUCTION

The increasing population and difficulties in setting up new landfill sites, demands some space in the existing landfill sites. Current municipal solid waste (MSW) landfills are generally operated by conventional sanitary techniques, where anaerobic conditions are being made with in landfill waste [6]. This technique reduces the contamination of the environment, but it also restricts the exposure of air and water to the MSW. This reduces the biodegradation rate and increases the landfill stabilization rate. The MSW landfill is considered stabilized when leachate is no longer a pollution hazard, gas production is negligible and the greater part of the settlement has occurred [2,3].

In order to increase the degradation rate of MSW, landfill sites are being operated either as anaerobic or aerobic bioreactors. Bioreactor creates the efficient conditions for microbial growth which helps in the decomposition of the waste and increases the stabilization and settlement, thus allowing for additional disposal of municipal solid waste [8]. Leachate recirculation in both aerobic and anaerobic bioreactor increases the moisture content and causes redistribution of nutrient and bacteria to MSW mass. There are some other factors which help in faster degradation of MSW in bioreactor such as waste shredding, compaction, pH adjustment and aeration as well as the addition of nutrients and increase in alkalinity [10]. In anaerobic bioreactors, the increased water content increases the rate of methane production which can be used as an energy source. The addition of the air stops the methane production, which is desirable in the area where CH_4 collection is not feasible [7]. Addition of the air in the bioreactor create the condition which results in the oxidation of the organic waste to CO_2 and H_2O, where by the organic nitrogen is mineralized to NH^{4+} is further oxidized by nitrification to NO_3^-, resulting in decrease in alkalinity and pH. Nitrification and denitrification may occur simultaneously in an aerobic bioreactor [9]. An aerobic condition increases the reactions that produce large amount of acids and reduce the pH, affecting solubility and sorption properties of organic and metal contaminants [3].

The objective of this study was to setup a laboratory scale aerobic bioreactor and to investigate the characteristics of the leachate such as BOD_3, COD, and pH.

The effects of leachate recirculation on the waste stabilization and waste settlement rate were also investigated.

2. MATERIALS AND METHOD

2.1. MSW Composition

The organic waste was collected from Jaypee University and other waste was collected form MSW landfill site of solan city. This waste was segregated manually. Shredded waste was used in the reactor and the waste was shredded manually. The shredding of waste theoretically may help to homogenize by size reduction and mixing, increase the specific surface area of the waste components for biodegradation, and increase the permeability by reducing impermeable materials and making easier the distribution of water [5]. Table 1 shows the composition of the municipal solid waste.

Table 1: Composition of MSW

	Organic	Paper	Plastic	Metal	Total
Weight (kg)	25	4	4	2	35
% age	71.43	11.43	11.43	5.71	100

2.2. Lab-scale Aerobic Reactor set-up

The simulated aerobic bioreactor consisted of a 175L cubic cell made of plexi glass (0.56×0.56m). The reactor is equipped with 6 ports; 3 ports were used for drainage and sampling while other 3 ports were used to add liquid and to check temperature. A container of 15 L was installed at the bottom of the bioreactor for the collection of the leachate. The leachate was recirculated and flushed over the top of the MSW manually. Air was injected into the reactor with the help of air pump.

2.3. Experiment operation

6 cm thick layer of aggregates was placed on the reactor which forms the bottom layer the reactor. Aggregates were added in the reactor to avoid the clogging of the drainage pipes. 35 kg of MSW was added into the reactor. The final density of the waste after compaction was 446.5 kg/m^3. A specific height of 25 cm was attained. The density is usually in the range 400-700 kg/m^3 full scale landfill and this was necessary to achieve a proper fluid flow through the lab MSW bioreactor [5]. The reactor is operated as aerobic to better understand the effect of aeration on solid waste degradation. Leachate collected in storage container is being recycled to reactor once per week; the air inlet at the top of the reactor is connected to an air pump which operates at 3litres/min for 12 hours a day to maintain aerobic conditions from start to end. Daily change in temperature was measured with the help of multi thermometer.

2.4. Analytical methods

Leachate samples were taken from the bottom of the tank to investigate the leachate quality, as well as the stability of the waste mass. Chemical oxygen demand (COD), biological oxygen demand (BOD_3), pH, were determined. All these analysis were performed according to the standard methods for the examination of water and wastewater [1].

3. RESULTS

3.1. COD-BOD_3 removal

COD and BOD_3 are used to determine the degradation of the municipal solid waste. From Fig. 3.1 we can see that the BOD has decreased from 30,600 to 6,770 mg/l within a few days which show the high degradation rate of organic matter. The COD in the leachate is expected to decrease in aerobic decomposition process which indicates the quantity of easily degradable organic compounds [7]. The initial COD was 35,190 mg/l and then it decreased to 14,500 mg/l as shown in fig 3.2. In Fig. 3.3 BOD_3/COD ratio is greater than 0.3 which shows that the waste is still young and has high biodegradability [4, 11].

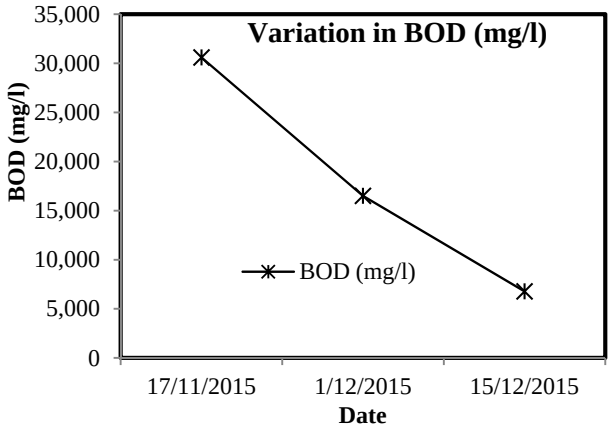

Fig. 3.1: Shows the variation in BOD with time

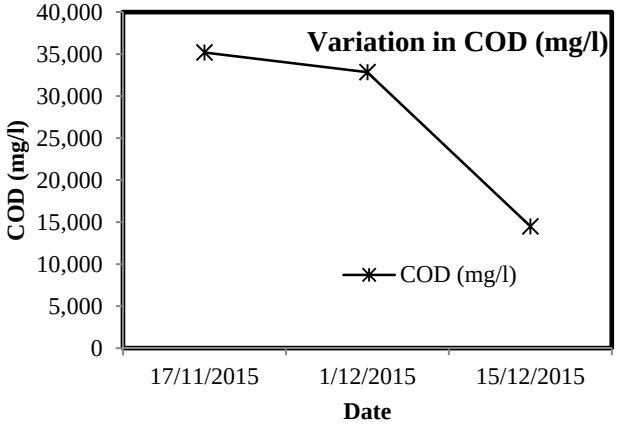

Fig. 3.2: Shows variation in COD with time

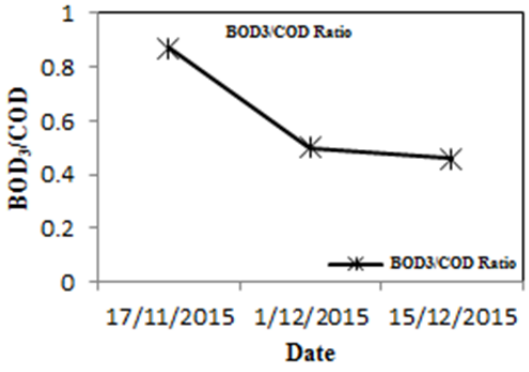

Fig. 3.3: Shows the variation of BOD/COD ratio with time

3.3. pH variations

The change of leachate pH for the reactor is given in Fig. 3.4. In the first week of the experiment the pH was acidic (4.61). The aeration of the reactor caused increase in the pH value and reaches up to 7 which is an optimum condition for microbial activity.

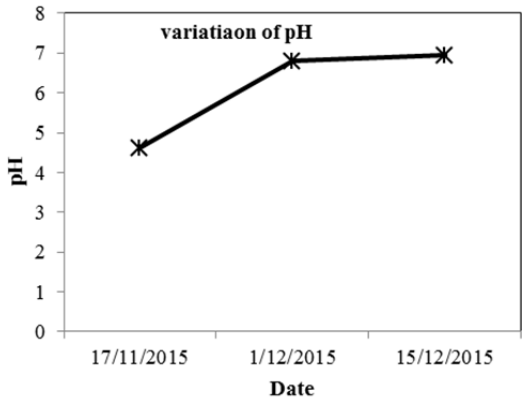

Fig. 3.4: Shows the variation in pH

3.4. Variations in settlement

The rate of landfill settlement is mostly depends on the waste composition, operational practices and factors affecting biodegradation [11]. The waste settlement occurred rapidly in the starting of the experiment this is due to physical and mechanical process, called as primary settlement [10]. In physical process settlement of the waste is due to the decrease in the void ratio of the waste which causes the densification of the waste and increases the settlement.

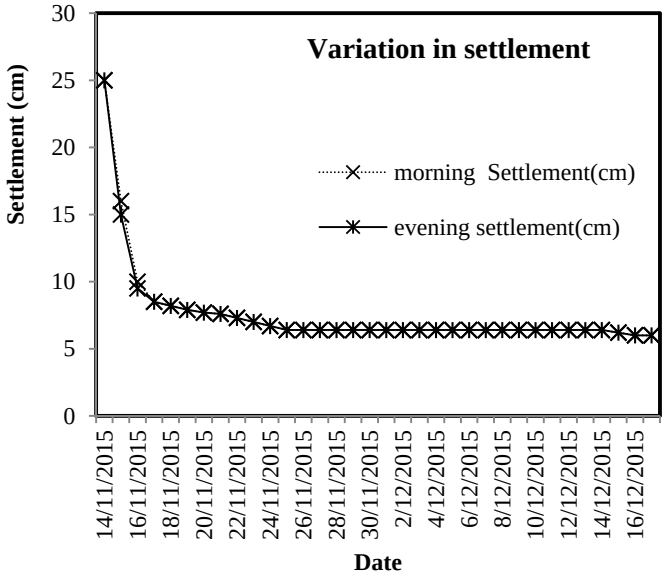

Fig. 3.5: Shows the variation of settlement with time

After 5 days of experiment rate of settlement decreases this is due to chemical and biological process, called as secondary settlement [10]. In secondary settlement of the waste is due degradation of organic waste by microorganism which is a slow process. Fig. 3.5 indicates the decrease in settlement with time.

3.5. Leachate production rate

In Fig. 3.6, the initial leachate production rate was high because initially settlement of waste was high and then it decreased with time. This decrease in the leachate flow rate is may be because of the absorption of liquid by the waste during recirculation process. Initial leachate production was 5 l/day after 34 days its production was 0.075 l/day.

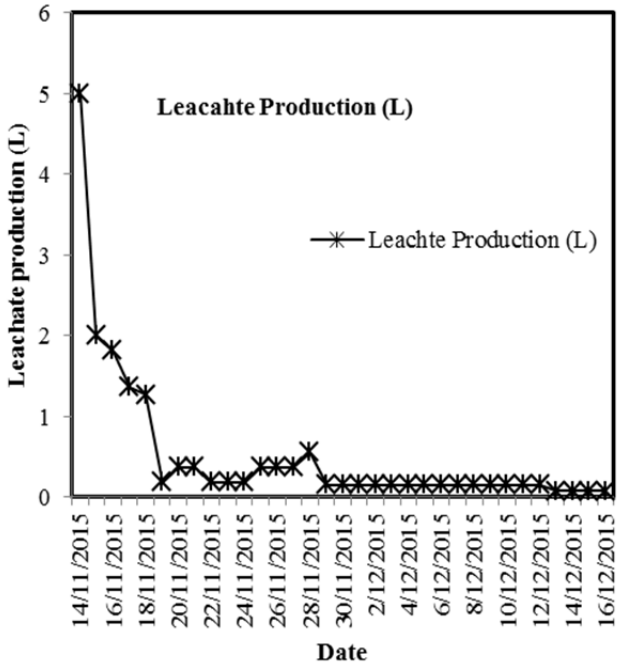

Fig. 3.6: Shows the variation leachate production with time

3.5. Variations in temperature

Changes in temperature reflect the degree of solid waste degradation. Fig. 3.6 shows the monitored temperature of bioreactor. The variation of temperature for the 34 days of the experiment ranged between 17 and 29 °C. This increase in the temperature is because of the aerobic degradation of solid waste which releases energy.

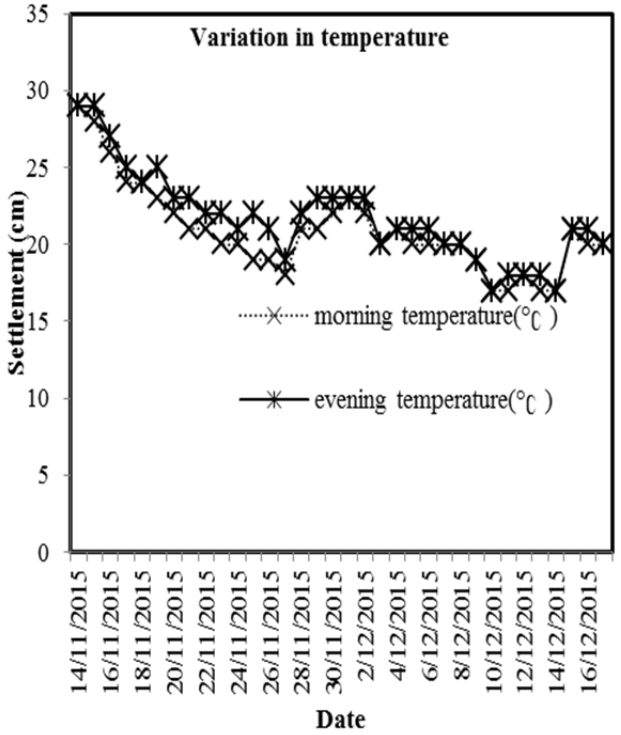

Fig. 3.6: Shows the variation in temperature with time

4. CONCLUSIONS

1. Initial BOD/COD ratio is found to be greater than 0.3 which indicate that the MSW used for the experiment is young. It is observed that BOD_3/COD greater than 0.3 indicates high biodegradability [4]. Hence it is concluded that the municipal solid used for the modeling of the bioreactor is young in age and highly biodegradable.
2. The increase in the rate of settlement can also be attributed to the leachate recirculation done weekly. It is observed that the settlement (degradation) occurred rapidly in the initial part of the experiment. The degradation of the MSW used in the modeling leads to densification of the waste**.** This reduces the initial void ratio and increases the unit weight of MSW. The reduction in void ratio (due to leachate flowing out from MSW) under the self-weight of MSW and the surcharge from the gravel layer is observed as settlement in the thickness of the waste layer
3. Another reason for the settlement is the intermittent air flow rate provided at every 12 hrs. This keeps the aerobic phase of degradation of MSW and supports the active microbial community**.**
4. The initial settlement of the waste is found to be high 10 cm (evening) and 9 cm (morning) which is then found to decrease to 1 cm daily. It can be concluded that since the void ratio of the MSW layer is decreasing with time, the leachate production rate is found to be less in the later stages of the experiment. The leachate production rate is found to decrease from 5 l/d to 0.074 l/d in 34 days.
5. It is observed that the leachate recirculation also leads to increase in the degradation of the MSW. This increase in the degradation can be accounted for enhanced microbial activity in the bioreactor. The leachate increases the moisture content of the bioreactor which provides the optimum environment for the microorganism to multiply.
6. The intermittent air flow rate (12 hrs. a day) and leachate recirculation (after every 7 days) provided in the bioreactor is found to increase the degradation of the MSW at a higher rate. The variation in the rate of settlement is found to change by 8 cm without and with leachate recirculation.

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