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Research Paper

Preferential flow in Landfill Simulating Reactors

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Abstract: *Uniform moisture addition/leachate recirculation is pre-requisite for consistent degradation of municipal solid waste in bioreactor landfills. The flow conditions in the landfills need to be investigated to determine the path followed by the moisture in the landfills. The present study investigates solute transport through moisture flow in landfill simulating reactors using sodium chloride as tracer. Four plexiglass reactors of dimensions 60cm height and 17cm diameter were used as landfill simulating reactors. Municipal solid waste samples were collected from the Wariana dump site located in Jalandhar city of Punjab state, India. Two reactors were packed with municipal solid waste at two different densities and other two reactors were loaded with organic solid waste again at two different densities. Reactors were flushed with water and a pulse of tracer was applied. Inflow of water was reestablished after the tracer application. Leachate samples were collected at regular time intervals. This investigation indicated the preferential flow paths in solid waste through the interpretation of breakthrough curves (BTCs). Nature of the waste and its compaction density affected the extent of channelization in the landfill simulating reactors.*

Key words: Moisture flow; Bioreactor Landfills; Municipal Solid Waste; Preferential flow.

Introduction

In developing countries, the disposal of most of the organically rich municipal solid waste takes place by open dumping; only a small portion is processed by composting. Gradually, these countries like china and India are shifting to sanitary landfilling equipped with bottom liners, daily covers, leachate and gas collection systems for waste disposal. Till now, sanitary landfills are operated on dry tomb technology by avoiding percolation of water through waste. The dry tomb technology decreases the rate of anaerobic decomposition of the biodegradable fraction of municipal solid waste. Therefore, the post closure care of landfills for several years becomes mandatory in such cases [1].

However, the concept of bioreactor landfills aims at leachate recirculation and/or water addition to enhance the rate of waste degradation anaerobically under optimum moisture conditions. The bioreactor landfills significantly increase the extent of organic waste decomposition, waste settlement and gas generation rates [2-3]. Improved opportunities for leachate treatment and storage; reduction of post-closure activities; and abatement of greenhouse gases are some other important applications of leachate recirculation [4].

Uniform moisture addition/leachate recirculation is the main requirement for bioreactor landfills. Municipal solid waste is highly heterogeneous and its diverse nature creates restricted channels and voids through which moisture movement takes place. The channeled flow influence the degradation of waste in the bioreactor landfill, making it unmixed, water deficient bioreactor [5-12].Tracer tests have been utilized by many researchers for determination of moisture flow with in landfills [12-15].

The objective of this study is to investigate the solute transport or moisture flow in landfill simulating reactors containing municipal solid waste and organic solid waste at two different densities by using sodium chloride as a tracer. The purpose to select organic waste for this study was to understand the behaviour of completely degradable faction in the bioreactor as compared to municipal solid waste. Tracer travel time distributions were derived from breakthrough curves.

Material and Methods

Solid Waste Material

Fresh solid waste samples were collected from the Wariana dump site located at Jalandhar city in the state of Punjab, India. Two different types of solid waste samples were used for the present study. Sample selection was done by coning and quartering method in accordance with ASTM standard test method D6323-98 [16]. The municipal solid waste consisted of shredded waste (size less than 4cm) containing composting material, paper, plastic, rags and the second sample was shredded organic solid waste consisting of fruit, vegetable and yard waste only as mentioned in Table 1. Size reduction of materials was achieved using knives and scissors so that moisture content of waste was not affected. After shredding, the fresh waste samples were immediately stored in black polybags and transferred to laboratory where these were refrigerated at 4°C before loading them into the respective reactors.

Landfill Simulating Reactors

Experiments were conducted using four reactors of plexiglass with diameter of 17cm and height 60cm. The schematics of one such reactor is shown in Figure 1. Each reactor contained a metallic lid having over head container of one litre capacity with a stopper to regulate the flow inside the container. A water distribution system was installed below the lid of reactor at the top to add liquid to the waste in the form of spray. Leachate was collected from the bottom of the reactor. A 5cm thick layer of 2.5cm gravel was placed at the bottom of each reactor for leachate drainage. Two nylon screens of 1mm diameter were placed above and below the drainage layer to retain waste and stop particles from leaching out. First two reactors were filled with 4.4kg of municipal solid waste and organic solid waste with wet weight compaction density of 622kg/m^3 in 40cm thick layers and labeled as A and C, respectively. The other two reactors were filled with 6kg of municipal solid waste and organic solid waste in 40cm thick layers with wet weight compaction density of 850 kg/m^3 and were tagged as B and D, respectively. Headspace of 15cm at the top was left in each reactor.

Tracer Tests

Tracer experiments were conducted to investigate hydraulic conditions in both the reactors. 11g of NaCl was dissolved in 150 ml of water and applied as tracer. Before applying tracer pulse, reactors were flushed with approximately 24 litres of water to decrease the background concentration of NaCl in the waste and also to create steady state flow conditions in the reactors. Pulse of NaCl was applied at the rate of 2.5ml per second. This flow rate was determined according to the precipitation data of Jalandhar city. The mean rainfall and mean rainy days in the city along with surface area of reactor were utilized to calculate this flow rate [17]. After the pulse application, water was sprinkled at the same rate till electrical conductivity of leachate matched with the conductivity that was before the application of tracer. 6 litres of water was sprinkled for 2400 seconds in all the reactors and leachate samples were collected at the regular intervals. Chloride concentrations in leachate samples were determined by argentometric titration method [18]. Breakthrough curves (concentration of tracer verses time) were plotted for these tracer experiments.

Results and Discussion

The breakthrough curves (BTCs) for the concentration of tracer in leachate samples with time were plotted for all the four reactors. Figure 2 and 3 represented BTCs for A and B reactors (containing municipal solid waste) respectively. Both the reactors A and B contained similar kind of waste but with different densities; A at wet waste compaction density of 622kg/m^3 and B at compaction density of 850kg/m^3. Figure 2 represented a typical positively skewed curve with a long tail for A reactor. The earlier peak pointed out preferential flow of moisture through domains of more mobile water in the waste and tail revealed the slow and sluggish flow through domains of less mobile water. Earlier part of the peak confirmed the channelized flow through heterogeneous waste in the reactor as indicated in previous literature [5-12]. This preferential flow or channeling results in downward movement of leachate at faster rate, resulting in differential degradation and settlement of waste in the landfills. Breakthrough curve for B reactor was found to be comparatively less skewed as compared to A reactor. Maximum concentration of tracer in A and B was observed at 7 min and 14 min respectively. The calculated values of skewness of concentration distributions in Figures 2 and 3 were 0.85 for A and 0.39 for B with municipal solid waste.

Similarly, Figures 4 and 5 represented BTCs for other two reactors containing organic solid waste; in C reactor waste placed at wet compaction density of 622kg/m^3 and in D reactor at density of 850kg/m^3.Positively skewed curves pointed out the real hydraulics of reactors and again confirmed the channelized flow through organic solid waste in both the reactors. Maximum concentration of tracer in the leachate sample was monitored at 12min for C reactor and at 16 min for D reactor. The values of skewness calculated for plots in Figures 4 and 5 were 0.26 and 0.13 for C and D reactors, respectively. C and D reactors with organic solid waste indicated lesser degree of skewness as compared to A and B reactors containing municipal solid waste, that could be an indication of relatively symmetrical distribution and limited channelized flow in organic solid waste as compared to municipal solid waste. Lesser heterogeneity of organic solid waste than that of municipal solid waste might have limited the channelization of moisture flow in organic solid waste.

The maximum concentration of tracer in leachate sample was achieved earlier in reactors A and C with less compaction density as compared to B and D reactors with more compaction density. The increase in density might have decreased the channelization of wastes in reactors; therefore the retention time of solute has increased for the waste placed at higher density. The comparison between Figures 2 and 3 as well as between Figures 4 and 5 in terms of skewness indicated that the increase in compaction density has more pronounced effect on the municipal solid waste as compared to the organic solid waste in terms of decreasing channelization. Different components of municipal solid waste including its inert fraction might have helped it to attain less channelized flow at higher compaction density.

Conclusion

The present study has confirmed the occurrence of channeled or preferential flow in solid waste landfills. Nature of the waste and its compaction density affected the moisture movement in the landfill simulating reactors. Decreasing heterogeneity of the waste and placing it at appropriate density could be helpful in decreasing channels or increasing homogeneity of moisture movement in bioreactor landfills. Techniques enhancing waste stabilization like water/leachate recirculation through landfills are successful only in presence of uniform moisture distribution in landfill. Due to heterogeneous nature of waste, preferential or channeled flow in the landfills will ultimately delay the waste stabilization process in less preferred paths in the waste. So the techniques enhancing uniform moisture distribution in landfills need to be improved further. Segregation of waste to increase its homogeneity and its placement at appropriate density in a landfill might be useful to promote uniform moisture distribution and reducing preferential water flow through the waste.

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Table 1. Composition of Municipal Solid Waste and Organic Solid Waste

Waste Type	Waste Fraction	Percentage
Municipal Solid Waste →	Fruits and Vegetables	60
	Plastic	8
	Paper	8
	Rubber	2
	Rags	4
	Yard waste	7
	Inerts	11
Organic Solid Waste→	Fruits and Vegetables	96
	Yard waste	4

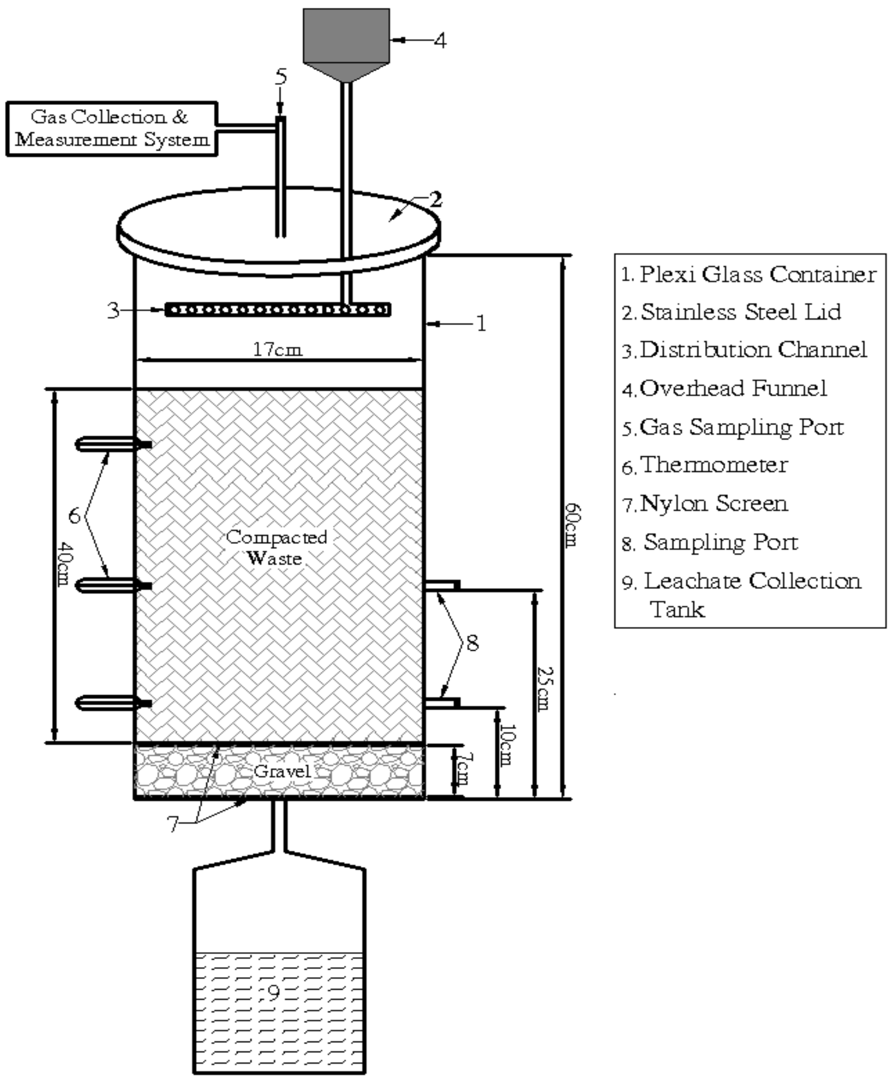

Figure 1. Landfill Simulating Reactor

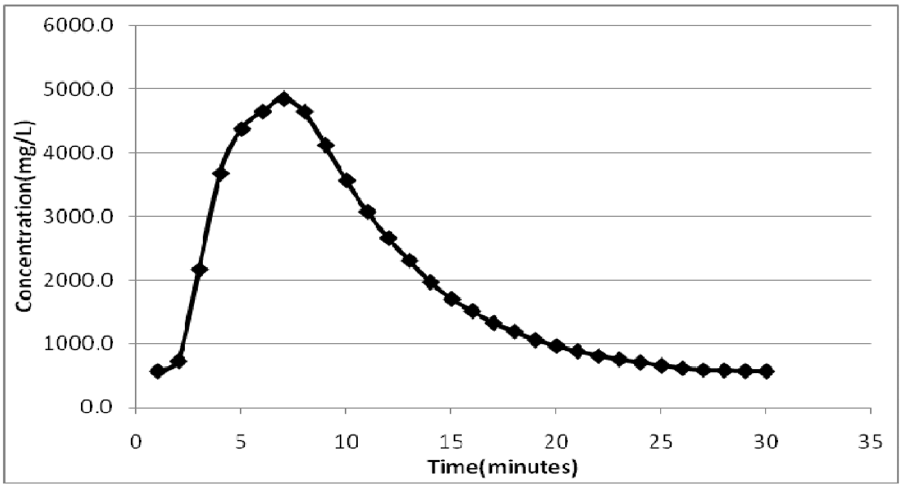

Figure 2. Breakthrough for reactor A with municipal solid waste

Figure 3. Breakthrough curve for reactor B with municipal solid waste

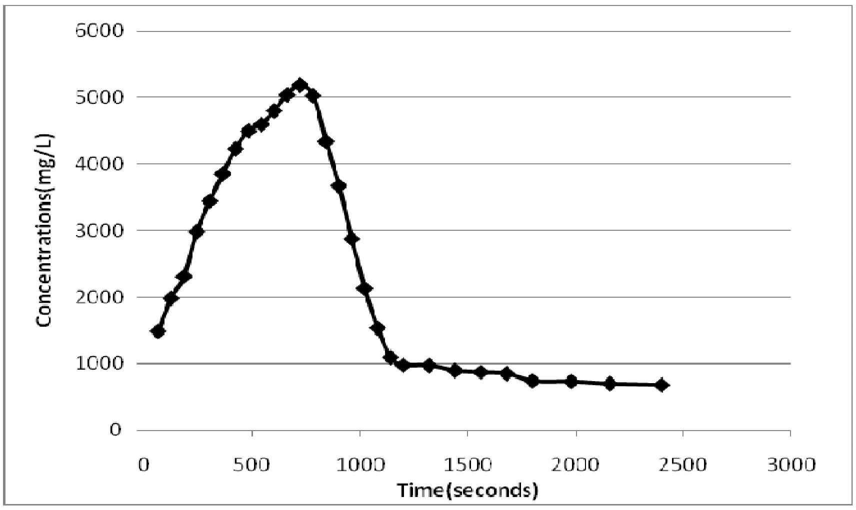

Figure 4. Breakthrough curve for reactor C with organic solid waste

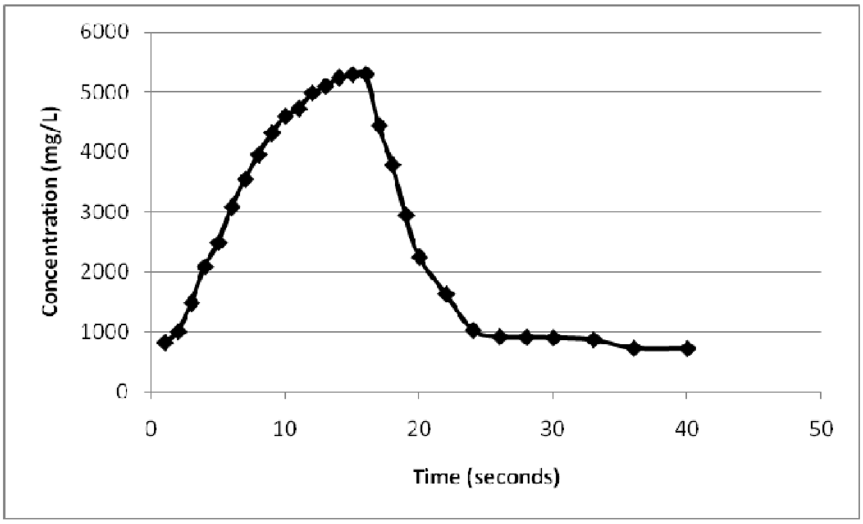

Figure 5. Breakthrough curve for reactor D with organic solid waste