Improving Leachate Quality By Leachate Recirculation Using Anaerobic Bioreactor Landfill

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Abstract

Anaerobic bioreactor landfill is one of the large scale solid waste management methods. Conventional landfill byproducts pollute environment. Leachate and landfill gases are the main byproducts of conventional landfill. Leachate treatment is very expensive and escaping of leachate cause soil as well as ground water pollution. Anaerobic bioreactor landfill reduces all the problems related to conventional landfill. Leachate quality improves by recirculation so leachate treatment is not needed and it reduces treatment cost. In this paper a study is carried out in vegetable waste to improve leachate quality using leachate recirculation at anaerobic condition. The experimental setup for the study is by using two reactors of 30cm diameter and 50cm height. One reactor is used for with leachate recirculation and another for without leachate recirculation. Samples of vegetable waste are collect and analyze for several properties like pH, moisture content, total dissolved solids, volatile solids etc. Before initializing the experiment add water for maintain the optimum moisture content on bioreactor with leachate recirculation. In one reactor, collected leachate recirculated back through the refuse mass. Analyze leachate properties like pH, total solids, BOD, COD, ammonia-Nitrogen, Iron, Alkalinity, Hardness, electrical conductivity etc. This study is carried out to investigate the effect of leachate quality and effect of leachate recirculation on vegetable waste anaerobically. And from the experimental results the percentage reduction is high and all parameters are within the range of effluent quality prescribed by schedule of Environment Protection Rules,1989 in recirculated reactor compared to the other.

Keywords: *leachate, leachate recirculation, bioreactor landfill, COD, BOD.*

1.0 Introduction

Nowadays and always waste disposal making a serious issue. There are so many waste disposal methods- landfill, biogas plant, incineration etc… but most of them making environmental pollution. For example incineration causes air pollution. And in conventional landfill, it produces water pollution, soil pollution and air pollution. So an advanced technology was invented to solve problems related to conventional landfill; that is bioreactor landfill.

Conventional landfill pollutes the environment by its by-products. The major by-products are leachate and landfill gases. 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. Proper treatment of the leachate has therefore been a challenging task. Leachate treatment is very expensive. The presence of heavy metals at high concentrations in landfill leachate usually cause toxic effects to microbes, making it difficult to treat biologically.

The most important and cost-effective method is liquid addition and management. Other strategies, including waste shredding, pH adjustment, nutrient addition, waste pre-disposal and post-disposal conditioning, and temperature management, may also serve to optimize the bioreactor process. Treatment of leachate is very difficult as the quantities and qualities of the leachate are highly variable and it is a very high strength wastewater [2]. Therefore problems may arise in the treatment of this wastewater. One of the most innovative and acclaimed methods of leachate treatment is the circulation of high strength leachate back to the landfill.

In this experimental study, leachate quality improves by leachate recirculation. And from experimental results the leachate recirculating reactor gave high percentage reduction values in all tested parameters. The leachate quality achieves within 9 weeks and the values are within the range prescribed by Effluent Standard.

2.0 Literature Reviews

Bioreactor landfill is a new technique. But so many studies are there related to bioreactor landfill. And almost all studies the leachate recirculated for obtaining the optimum moisture condition. Some of them are listed below.

Mayur A. Jirapure was conduct a study on leachate characterization and to treat it by leachate recycling or recirculation to achieve the highest MSW biodegradation rate and to observe the BOD, COD levels. The experiment to generate leachate artificially and recirculation was conducted in a lab scale model. Bioreactor operation was found to bring about extensive reduction in organic loads.

Delia Teresa Sponza *et al*., (2003) investigated the effects of leachate recirculation and the recirculation rate on the anaerobic treatment of domestic solid waste was investigated in three simulated landfill anaerobic bioreactors. A single pass reactor was operated without leachate recirculation while the other two reactors were operated with leachate recirculation. A lab-scale anaerobic simulated landfill reactor was used in order to reduce the COD, VFA levels in leachate produced and to enhance the methane production from solid wastes taken from the kitchen of Engineering Faculty Campus in Izmir, Turkey and recovery of methane from the leachate.

M. Warith *et al*., (2005) published a paper provides a review of the biodegradation processes and the mechanisms in landfill ecosystem, technologies applied in bioreactor landfills, and the development of the bioreactor landfill. The paper by Mostafa Warith (2007) presents the results of an experimental study carried out to determine the effect of solid waste size, leachate recirculation and nutrient balance on the rate of municipal solid waste (MSW) biodegradation. The study indicated that the smaller the size of the MSW the faster the biodegradation rate of the waste. In addition, the paper presents the results of leachate recirculation on solid waste biodegradation in a full-scale landfill site, which is located in Nepean, Ontario, Canada.

The study of Ma. C. Hernandez- Berriel *et al.*, (2010) was to determine the appropriate moisture regime, attained by leachate recycling, to achieve the highest municipal solid waste (MSW) biodegradation rate. To this end, leachate characteristics, methane production rate and change in degraded refuse were studied. ANOVA and Turkey's HDS revealed significant difference in leachate concentration characteristics when using different recycling volumes. Maximum methane production rate was found in the 70% MC regime, whereas the highest volume was found to produce a wash out effect in the refuse matrix.

As per study results from Chandetrik Rout *et al.*, (2010) the purpose of this study is to determine the impact of leachate recirculation on stabilization 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. 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 stabilization 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 stabilization.

3.0 Methodology

The underlying principle of the bioreactor landfill is that by optimizing operational control and environmental conditions within the waste (especially moisture content), more rapid and complete degradation of waste may be achieved. Bioreactor technology is a process based technology which involves physical, chemical and biological process with proper leachate management to recover bioenergy in the form of landfill gas and residue as manure. Physical process **-** Physical process involves, shredding of the waste to uniform size, proper mixing of the waste etc. Chemical process **-** Chemical process for enhancement of microbial growth involves leachate recirculation, pH adjustment, addition of buffers and nutrients etc. Biological process **-** Bioreactor landfill operates under optimal anaerobic environmental conditions for enhancement of bio-degradation process.

Leachate from a landfill varies widely in composition depending on the age of the landfill and the type of waste that it contains. It can usually contain both dissolved and suspended material. The generation of leachate is caused principally by precipitation percolating through waste deposited in a landfill. Once in contact with decomposing solid waste, the percolating water becomes contaminated and if it then flows out of the waste material it is termed leachate. Contaminated leachate treated well before disposal. There are many methods for leachate treatment. But leachate treatment is very expensive.

One of the leachate treatment methods is leachate recirculation. The produced leachate recirculated back in to the landfill. This liquid addition method is known as bioreactor landfill. It improves leachate quality, faster waste degradation rate and higher gas production rate.

Leachate quality improves with time. An experimental study was done to compare the effect of leachate recirculation and without leachate recirculation. Leachate recirculation is affects the moisture content. And optimum moisture content helps for degradation rate and gas production rate.

4.0 Materials and Methods

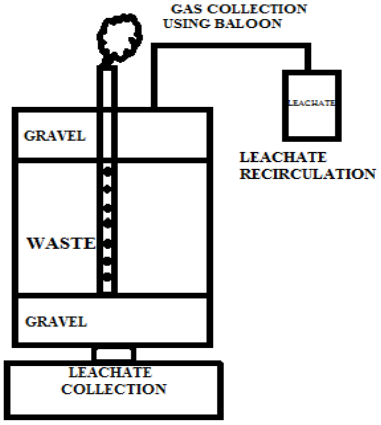


Figure 1. Experimental setup for study

Reactor: Construct 2 plastic reactors, cylindrical in shape with diameter 30cm, height 50cm. Both have perforations at bottom.

Sample collection: 20Kg vegetable waste was collected from Sakthan market, Thrissur. Then shredded the waste manually and mix uniformly. Vegetable sample was taken and analyse the waste. Parameters of pH, moisture content, Total dissolved solids and volatile solids are analyzed.

Table 1.Waste sample analysis results

No	Parameter	Value
1	pH	5.8
2	Moisture content	45.76%
3	Total dissolved solids	5370ppm
4	Volatile solids	4580 ppm

Gravel packing: Collected 40-20mm size gravel. 25Kg of gravel is used.

Reactor setup: First added 10cm of gravel layer then 10Kg of shredded waste again 10cm gravel. From moisture content analysis added water to obtain optimum moisture content. Nearly 2L water is added. Then cow dung is added in the ratio of 1:20 i.e cow dung: waste ratio. Cow dung was added to facilitate the enzymatic hydrolysis or extracellular depolymerisation of polymers such as carbohydrate, fat and protein. Wait a week for leachate production. Add 500 ml of water each week to generate leachate.

Leachate collection: Leachate collected in plastic bucket of 5L capacity. 100ml leachate sample is taken and analyze the sample weekly. pH, Chemical oxygen demand, Biochemical oxygen demand, Iron, Ammonia Nitrogen, Alkalinity, Hardness, Total dissolved solids, Total suspended solids, Volatile solids, Electrical conductivity are analysed. Leachate recirculated in 1st reactor.

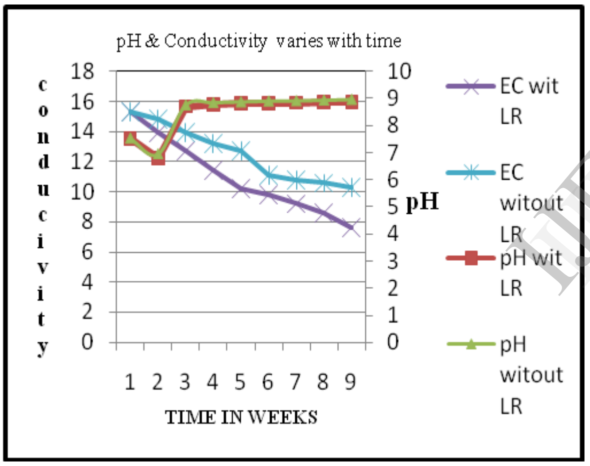
Leachate recirculation: Leachate collected in plastic bucket and recirculated by flow adjustment. Flow adjusted to drop the full leachate into the reactor within 5-6 days. Take leachate samples every week.

Gas collection: Gas collected by means of perforated PVC pipe of diameter 20mm. And balloons are used for gas collection. Process repeated for obtain leachate quality as per effluent standards.

5.0 Results and Discussions

The performance of reactors in the treatment of vegetable waste and quality of leachate was studied. The removal efficiencies were also discussed. The quality of leachate varies with time and it gave high removal efficiencies in leachate recirculating reactor compare to the other one. A comparative study between two reactors results are described below.

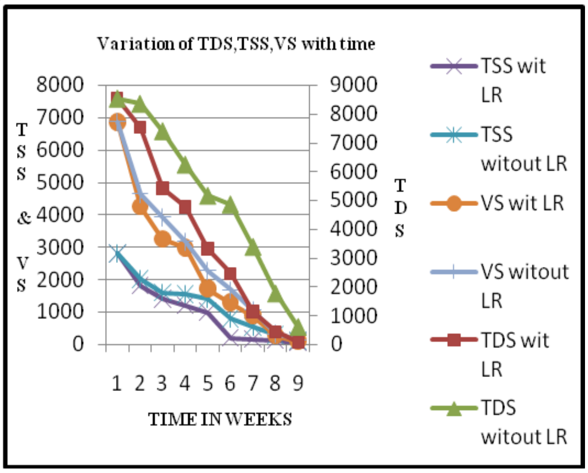
5.1. pH and Conductivity variation with time



The variation of pH over time is provided in below graph. The first two weeks of testing represents the initial adjustment and transition of waste degradation from aerobic to anaerobic phases. In reactor 1, pH varies with 6.8 to 8.87. In reactor 2, pH varies from 6.95 to 8.96. The initial pH decreased and reached to 6.8 in reactor 1 and 6.95 in reactor 2 on 2nd week. The 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 acids and bi carbonic acid and bicarbonate ion concentrations consuming H^+ ions. Effluent water quality standard values for pH is 5.5 to 9.0 which used for inland surface water, public sewer and land for irrigation. The 9th week pH values were within the standard values prescribed by Effluent water quality standard values.

The conductivity of leachate reflects its total concentration of ionic solutes and is a measure of solution's ability to convey an electrical current. In both the reactors, the change in leachate conductivity with time followed a similar trend as shown in below graph. The EC in reactor 1 varies from 15.3mS to 7.6mS and in reactor 2 varies from 15.3mS to 10.3mS. The conductivity is mainly due to the presence of charged ions. The charged ions were reduced by time so the conductivity also decreases with time.

5.2. Variation of Total Solids with time

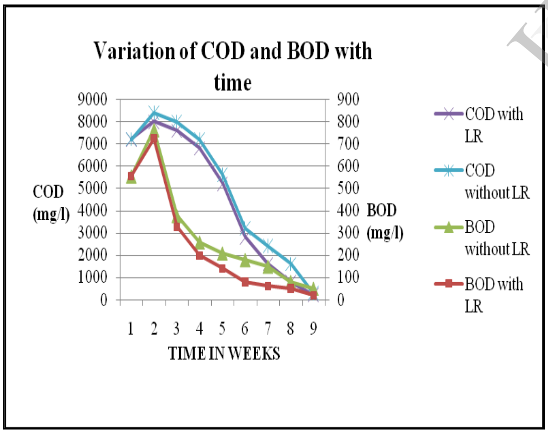


The dissolved solids are charged particles and cannot be settled or removed using preliminary treatment. Total dissolved solids in leachate reduced to formation of colloidal form. This is due to storage of leachate. Variation in reactor 1 ranges from 8520ppm to 80ppm. Variation in reactor 2 ranges from 8540ppm to 600ppm.

Total suspended solids are decreases with time. It is because of storage of leachate and suspended particles are settled in collecting basin. Variation of total suspended solids in reactor 1 ranges from 2800ppm to 60ppm and in reactor 2 ranges from 2800ppm to 120ppm. Suspended solids are settled with time and it reduces suspended solids concentration in leachate. As per ffluent water quality standard values for TSS is 100 mg/l which used for inland surface water, 600 mg/l public sewer and 200 mg/l land for irrigation.

Volatile solids are decreased with time. Volatile solids are volatilizing by storing leachate. Variation in VS in reactor 1 ranges from 6857ppm to 91ppm and variation in reactor 2 ranges from 6857ppm to 135ppm.

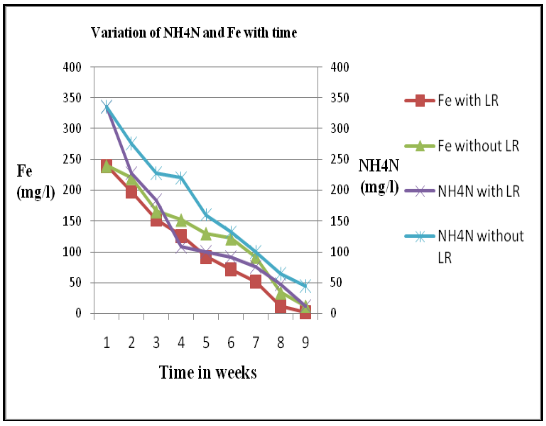
5.3. Variation of COD and BOD with time



Biochemical oxygen demand means the amount of oxygen required to degrade the biodegradable portion in the wastes. Variation in BOD in reactor 1 varies from 722.7mg/l to19.8mg/l and variation in reactor 2 varies from 762.3mg/l to 49.5mg/l. In both of the reactors, in the 2nd week the values reaches maximum and started to decrease. The reason for this decrease in BOD is due to quick degradation of waste. This may be because of faster degradation of waste by microbes which were present in cow dung. Percentage removal in reactor 1 and reactor 2 were observed as 97% and 93% respectively. As per effluent water quality standard values for BOD 30 mg/l which used for inland surface water, 350 mg/l public sewer and 100 mg/l land for irrigation.

The chemical oxygen demand means the amount of oxygen required to degrade the biodegradable and non biodegradable portion in the waste. Variation in COD in reactor 1 varies from 8000mg/l to 200mg/l and variation in reactor 2 varies from 8400mg/l to 280mg/l. In both of the reactors, in the 2nd week the values reaches maximum and started to decrease. The reason for this decrease in COD is due to quick degradation of waste. This may be because of faster degradation of waste by microbes which were present in cow dung. Percentage removal in reactor 1 and reactor 2 were observed as 98% and 96% respectively. As per Effluent water quality standard values for COD is 250 mg/l which used for inland surface water, public sewer and land for irrigation.

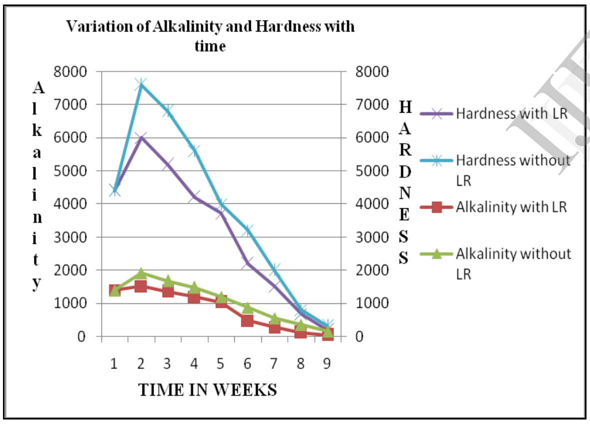
5.4. Variation of Ammonia Nitrogen and Iron with time



Ammonia nitrogen values decreases with time. The variation in reactor 1 ranges from 336mg/l to 12mg/l and in reactor 2 values ranges from 336mg/l to 44mg/l. As per Effluent water quality standard values for NH_4N are 50 mg/l which used for inland surface water, public sewer and land for irrigation.

Iron concentrations in both reactors were decreases with time. The reason for decrease in values is due to formation of compounds. It is due to storage of leachate. The variation of values in reactor 1 ranges from 240mg/l to 2mg/l and in reactor 2 ranges from 240mg/l to 12mg/l. As per effluent water quality standard values for Iron is 3 mg/l which used for inland surface water, public sewer and land for irrigation.

5.5. Variation of Alkalinity and Hardness with time



The alkalinity values in reactor 1 ranges from 1520mg/l to 48mg/l and in reactor 2 ranges from 1920mg/l to 160mg/l. The alkalinity values were decreases with time.

The hardness values were decreases with time. The variation of values in reactor 1 ranges from 4800mg/l to 40mg/l and in reactor 2 ranges from 6000mg/l to 200mg/l.

5.0 CONCLUSION AND FUTURE ENHANCEMENT

Comparison of bioreactor landfill with and without leachate recirculation is studied. The leachate recirculation is a feasible way for leachate treatment. Landfill leachate recirculation improved the quality and got the results within 9 weeks. And all the tested parameters were within the range prescribed by effluent standard. The pollution indicates BOD and COD removes 97% and 98% respectively. And the treated leachate will disposed into inland surface water. And landfill leachate recirculation reduces the treatment cost. Leachate recirculation gave optimum condition for waste stabilization and gas production. Waste degraded within 9 weeks. From the comparative study, leachate recirculating reactor will gave more effective results from other. Landfill leachate management with leachate recirculation is a promising and challenging strategy. The feasibility of leachate recirculation is reducing the overall leachate loading for treatment and in enhancing the degradation rate of waste. Anaerobic bioreactor landfill increases the waste stabilization and gas production rate. It solved all the problems due to conventional landfill. Bioreactor landfill increases the leachate quality. Bioreactor landfill reduces additional leachate treatment. And gas produced used for energy production. Anaerobic bioreactor landfill is an effective treatment for waste management.

6.0 FUTURE ENHANCEMENT

The bioreactor landfill provides control and process optimization, primarily through the addition of leachate or other liquid amendments, the addition of sewage sludge or other amendments, temperature control, and nutrient supplementation. Each phase in a bioreactor landfill shows the significance of the microorganism's role in biodegradation. Thus, adjustment of factors that support the microorganism's activity is necessary. The fundamental factors that can affect the efficiency of degradation in a landfill system are discussed below. Relevant references provide detailed discussions of these factors. A brief description of some important factors is discussed herein.

6.1. Waste Composition- Waste composition is one of the most important parameters affecting bioreactor landfill performance. Normally, higher gas yield could be achieved from easily biodegradable wastes like food waste, paper and garden cuttings compared to hardly biodegradable materials like plastic, wood and rubber. Percentage of easily biodegradable material is dependent on the solid waste management program.

6.2. Seeding of microorganisms- Seeding of microorganisms in the anaerobic process has the primary objective of accelerating waste degradation by increasing the population of slow-growing microorganisms such as methanogenic bacteria. Favorite seedings that give positive effects are digested sewage sludge and old anaerobically degraded refuses. However, negative effects can occur while using low pH septic tank sludge

6.3. Buffering capacity- Acidogenesis results to accumulation of acid. Naturally, the process involves self-recovery but takes a long period of time. In order to avoid excessive accumulation of acid, buffer substances can be added to prevent the inhibition of methanogenic activities. Calcium carbonate ($CaCO_3$), sodium carbonate (Na_2CO_3) and potassium carbonate (K_2CO_3) were found to be effective in maintaining the buffering capacity in landfills. Careful operation of the landfill bioreactor initially through slow introduction of liquids should minimize the buffering needs.

6.4. Shredding/Size Reduction- Reduction of particle size by increasing the ratio of surface area to mass affects the biodegradation process. Reduction provides more uniformity of wastes and thus the biodegradation could be enhanced. It has been suggested that shredding may help to remove moisture barriers caused by impermeable materials, and to improve the water content distribution in the waste. In addition, size reduction also supports the hydrolysis and acidogenesis step to quickly release acid to the system. Thus size reduction should take place concurrently with buffering and/or seeding.

6.5. Compaction- Higher compaction under well-mixed static landfill condition yielded higher methane gas volume. If a waste is relatively dry, increasing the compaction (or the dry density) may significantly speed up the degradation processes. This positive effect can be explained by the higher moisture content (by volume) available in the more compacted solids which may help to enhance the distribution of nutrient and the contact between substrates and bacteria. However, for wet waste, an increase in dry density may actually slow down methane production. This is due to the development of an undesirable early intensive acid phase, over-stimulated by high moisture.

6.6. Cover soil- Application of daily cover soil is often prescribed to improve the hygienic and aesthetic standard of the landfill. The daily and final cover soil is the principal source of organisms responsible for the decomposition of refuse. Exceptional, positive effects of cover soil might be expected by maintaining the buffering capacity of the landfill. However, leachate concentrations were higher from shallow lysimeters having covered soil.

6.7. Pre -Treatment of Wastes- The provision of waste pretreatment by aerobic conditioning (composting) prior to landfilling helps reduce the easily biodegradable substances and prevents excessive acid accumulation in the landfill. It can also be performed after completion of landfill by providing aeration to recirculated leachate. The basis of the concept is to allow the more readily degradable organic material in the waste to first degrade by aerobic processes via composting, thereby moderating the development of an otherwise intensive acid phase in the later anaerobic degradation.

6.8. Enzyme addition- The hydrolysis process in a landfill system is promoted by the fermentative bacteria and the same can be controlled and enhanced by industrial cellulosic enzymes. Their results suggested that it is viable to intensify both acidogenic and methanogenic conditions by enzyme addition.

7.0 References

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