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Review article

REVIEW ON ANAEROBIC TREATMENT OF MUNICIPAL SOLID WASTE WITH LEACHATE RECIRCULATION

Mansi Rastogi*, Rajni Hooda[1] and Meenakshi Nandal[2]

*Ph.D Scholar, [1]Ph.D Scholar, [2]Assistant Professor
Department of Environment Science, Maharshi Dayanand University, Rohtak
rastogimansi86@gmail.com, minievs9@gmail.com

ABSTRACT: Anaerobic bioreactor landfills are the most popular method to treat municipal solid waste as they rapidly stabilize waste, enhance leachate treatment along with increased landfill gas generation for cost-effective energy recovery and reduced post closure maintenance period. Leachate recirculation is one of the methods to apply in bioreactor to eliminate the leachate treatment and ground water contamination. The landfill leachate is characterized by high contents of organic and inorganic compounds which gradually decrease and depict the stabilization of municipal solid waste. Concentrations of these compounds in leachate depends on the type of waste, its susceptibility to dissolution, chemical and biological degradation and the volume of water running through the waste. The objective of this review paper is to highlight the effects of leachate recirculation on waste stabilization in a simulated bioreactor and to depict that the bioreactor efficiently stabilizes the waste mined from dumpsite by enhancing organic degradation.
Key words: Leachate, Recirculation, Bioreactor, Dissolution.

INTRODUCTION

The Bioreactor landfills offer a sustainable way to achieve increased waste degradation along with benefits such as enhanced landfill gas (LFG) recovery, reduction in leachate pollution potential and rapid increase in landfill volumetric capacity. Insufficient allocation of financial resources in the waste management sector, acceptance of the status quo and a lack of awareness among both the public and politician of environmental and health concerns are the root cause of the low quality of waste services [43].

Bioreactor landfill is a sanitary landfill that transforms and stabilizes the readily and moderately decomposable organic waste constituents within few years by enhanced microbiological processes and increase in effective organic waste decomposition, conversion rates and process rate. Bioreactor technology is selected by considering four reasons:1) to increase potential for waste to energy conversion, 2) to store and/or treat leachate, 3) to recover air space and 4) to ensure sustainability [34]. Anaerobic digestion of solid waste is more desirable than combustion or gasification as a waste-to-energy technology because of the ability to extract energy (biogas) and generate nutrient-rich digestate material that can be used as a fertilizer [1].

The composition of urban MSW in India was studied by Annepu *et al*., [3] he states that it consist of 51% organics, 17.5% recyclables (paper, plastic, metal, and glass) and 31 % of inerts. The moisture content of urban MSW is 47% and the average calorific value is 7.3 MJ/kg (1745 kcal/kg) as shown in figure 1. According to CPCB and NEERI, 2010 the composition of MSW in the North, East, South and Western regions of the country varied between 50-57% of organics, 16-19% of recyclables, 28-31% of inerts and 45-51% of moisture. The calorific value of the waste varied between 6.8-9.8 MJ/kg (1,620-2,340 kcal/kg).

Degradation MSW

A high degree of synergism and interspecies interactions is involved in anaerobic bio degradation, which include, acetogenic, hydrolytic and the methanogen bacterial phases [9]. As stated by [11] anaerobic degradation is a two-stage process viz-anaerobic respiration and fermentation. Anaerobic breakdown of MSW results in formation of volatile fatty acids, ethanol, lactate, succinate and gases as hydrogen, carbon dioxide. Fermentation is favoured by a low hydrogen ion (H^+) concentration.

Acetogens can be classified into 2 groups; hydrogen producers, which consume alcohols and organic acids and form acetic acid and hydrogen gas while the other group hydrogen consumers utilize carbohydrates, hydrogen, carbon dioxide and produce acetic acid. According to Vaidya R, [41] the process of methanogenesis is inhibited at greater VFA concentration due to decrease in pH in the initial acid formation phase. Subsequently, metals precipitate as hydroxides, sulfides and carbonates due to mobilization and complex as VFA. Cellulose is the primary constituent that undergoes decay in a landfill. Bookter and Ham, [9] determined that cellulose ranged from 8-30 % in well-decomposed landfills .Pathways for cellulose metabolism was studied by Tsao, [40]. The study states that cellulose is a linear homopolymer of anhydrous units linked by beta-D-1,4 glucosidic bonds. In landfills it is uptaken after enzymatic hydrolysis and hydrolyzed in the acidic phase of anaerobic digestion.

Phases of MSW decomposition and stabilization

Stabilization of waste includes physical and chemical reactions within the bioreactor landfill [39]. Environmental conditions which significantly impact on biodegradation include pH, temperature, nutrients, absence of toxic material, moisture content, particle size and oxidation reduction potential [32]. The stabilization of MSW proceeds in five sequential phases as shown in figure 2. The variation in rate and characteristics of leachate production and landfill gas generation can be used for monitoring stabilization of MSW landfill [39, 32, 24].

Phase I: Initial adjustment phase

Leachate is produced during this phase as a result of releasing of moisture during compaction and short-circuiting of precipitation through the MSW landfill. Biological decomposition occurs under aerobic conditions where oxygen present in the void spaces is rapidly consumed then produces carbon dioxide. Microorganisms are provided from soil material or other sources such as leachate recirculation, sludge, etc.

Phase II: Transition phase

In this phase due to depletion of oxygen there is transformation from aerobic to anaerobic condition within landfill, nitrate and sulfate act as electron acceptors in biological conversion reactions and reduced to nitrogen gas and hydrogen sulfide gas, along with displacement of oxygen by carbon dioxide. Due to organic acids and elevation in carbon dioxide, pH of the leachate starts dropping. The COD and VFA emerge during this phase.

Phase III: Acid formation phase

In this phase conversion of biodegradable organic content to intermediate volatile occurs due to biological activities of microorganisms and continuous hydrolysis (solubilization) of solid waste. Decreasing pH values and fatty acids at high concentrations are observed, accompanied by metal species mobilization. Rapid consumption of substrate and nutrients occurred in this phase.

Phase IV: Methane fermentation phase

In this phase methanogenic bacteria consume intermediate acids from phase III and converted to methane and carbon dioxide. Sulfate and nitrate are reduced to sulphides and ammonia, respectively. The pH values increase by the bicarbonate buffering system, this condition will support the growth of methanogenic bacteria. Heavy metals are removed by compellation and precipitation.

Phase V: Maturation phase

In this phase, due to limited nutrients and available substrate biological activities slows down. Gas production drops dramatically and leachate strength stays steady at lower concentrations. Oxygen and oxidized species may reappear slowly. However, the slow degradation of resistant organic fractions may continue with the production of humic substances. Humic acid and fulvic acid, which are difficult to process further biologically, are formed in this phase.

Generation of biogas in landfill

Visvanathan *et.al.*, [42] states that the biological oxidation of methane gas would be an inexpensive gas treatment system to reduce greenhouse gas emitted from landfill. Methane (CH_4) and carbon dioxide (CO_2) are predominating but collection LFG for energy recovery is not economical and inherent risks are associated with LFG management [38]. The CH_4 generated in landfills typically excess of 45% of the total landfill gases and over 20 times more harmful than CO_2. Landfill gas controlling system is employed to prevent emission of LFG into the atmosphere or the lateral and vertical movement through the surrounding soil. Furthermore, collected LFG can be used for production of energy. As open dumpsite is a predominant MSW disposal method in Asia, the methane emissions from the MSW shallow dumpsites that are without cover layer is less due to their more or less anoxic status [19]. According to a study by Pacey *et al.,* [30] the bioreactor landfill gas extraction system requires installation of proper equipments to avoid odour problems and efficiently controlling gas.

Leachate Mechanism

Leachate Generation

Leachates are defined as the aqueous effluent generated as a consequence of rainwater percolation through wastes, biochemical processes in waste's cells and the inherent water content of wastes themselves.

Leachates may contain large amounts of organic matter (biodegradable, but also refractory to biodegradation), where humic-type constituents consist an important group, as well as ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts. The removal of organic material based on chemical oxygen demand (COD), biological oxygen demand (BOD) and ammonium from leachate is the usual prerequisite before discharging the leachates into natural waters [5]. In open dumps, the material that leached would be absorbed into the ground and percolated and move into ground water, surface water, or aquifer system. In the landfill, as the liquids migrates through the waste it dissolves salt, picks up organic constituents and leaches heavy metals. This "landfill liquor" could be a potential potent polluter of soil and water as the organic strength of landfill leachate can be 20 to 100 times greater than the strength of raw sewage.

Leachate Recirculation

Leachate is produced when water percolates though the dumped wastes and uptakes the organic and inorganic products from both physical extraction, hydrolytic and fermentative process after satisfying the field capacity of the waste. Leachate is the portion of the precipitation which comes in contact with the waste. Leachate recirculation is an attractive option as it achieves a decrease in the total volume of leachate to be treated or disposed and a reduction in the degradable components of the leachate [27]. The Design of a typical bioreactor has been shown in figure 3.

Barlaz *et al*., [4] demonstrated that increase in moisture content along with leachate recirculation has shown increased biological activity (methanogenesis) and decomposition. A similar study states that the rapid development of methanogen bacteria in bioreactor landfill is the result of high moisture content. Similarly, Gurijala and Sulfita, [18] specified that moisture content in the range of 50% to 60 % was best for methanogenesis. According to San and Onay, [36] leachate recirculation in a landfill bioreactor is an effective way to enhance the microbial decomposition of organic fraction of municipal solid waste. Pouech *et al*., [31] investigated the usefulness of leachate recirculation to enhance the biodegradation and the leaching of the easily leachable components.

A laboratory scale study conducted, using two lysimeters filled with municipal solid waste mined from dumpsite to simulate the leaching of pollutant loads from controlled dumps and to assess the effect of leachate recirculation on waste stabilization depicted leachate quantity and quality, biogas composition, settlement and characteristics of susbtrate that were analysed over a period of two years. Leachates from both the lysimeters attained stabilization within 600 days as reflected by the pH, VS/FS, COD/DOC in leachates and biogas compostion. TKN and ammonical nitrogen in leachate from the lysimeter in recirculating mode reduced by 50% in one year. The results suggested that the leachate recirculation in old dumps can leach out both organic and inorganic compounds from the partially degraded waste [21].

Landfill leachate normally contains high concentrations of organic matter, nutrients, pathogens and heavy metals, and cause serious pollution of surface and groundwater sources so proper collection and treatment is necessary. Ahn *et al*., [2] and Bohdziewicz *et al*., [8] state that in recent years significant attention has been given to landfill leachate treatment for municipal areas. Numerous lysimeters and field tests were done by Chan *et al*., [10], Erses and Onay [12] and San and Onay, [36] to determine the impact of leachate recirculation on stabilisation of municipal solid wastes. Leachate recirculation is more effective on anaerobic degradation of solid waste than non recirculated degradation [35]. Leachate quality was determined in terms of pH, electrical conductivity, calcium, magnesium, total kjeldahl nitrogen, phosphate and chemical oxygen demand (COD) 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 and the following parameters were analyzed from each sample: pH, EC, Ca^{+2}, Mg^{+2}, TKN, PO_4 and COD. The maximum COD removal observed was 80.30% in reactor R1 and 89.93% in reactor R2 as the daily recirculation strategy has a positive effect related to COD removal, pH stabilization and other parameters.

The recirculation of the leachate through a bioreactor results in increased removal of the pollutants in the leachate [16]. The laboratory studies reported that after the 3rd recirculation the reduction in COD, BOD, colour and hardness was 98.34 %, 98.57%, 98.75% and 95.31%, respectively. A Reduction of 82-99 % in the heavy metal content such as cobalt, iron, lead, cadmium, zinc, manganese, copper and nickel was recorded. In the laboratory, an artificially prepared raw leachate was circulated through the reactor at the rate of 175 - 525 litres/m^3 of MSW through a bioreactor column of 110 mm PVC pipe filled with a 0.5 m. high MSW layer. Yao *et al*., stated that codisposed landfill with leachate recirculation could facilitate the stabilization of landfill. A laboratory scale study to assess the effect of leachate recirculation on waste stabilization by analysing the leachate quantity and quality, biogas composition, settlement and characteristics of substrate over a period of two years [21]. Overall waste volume settlement during the study period (600 days) in controlled and bioreactor landfills was 18% and 22%. In the experiment two lysimeters were filled with municipal solid waste mined from dumpsite to simulate the leaching of pollutant loads from controlled dumps. Leachates from both the lysimeters attained stabilization within 600 days as reflected by the pH, VS/FS, COD/DOC in leachates and biogas composition. During the recirculating mode in Ist year, TKN and ammonical nitrogen in the leachate reduced by 50% in the lysimeter.

Effects of leachate recirculation on anaerobic treatment of municipal solid waste

Waste degradation and the landfill's gas production rate is accelerated by leachate recirculation. Leachate is anoxic, acidic, high COD, high sulfate and metal ion and could cause groundwater contamination so leachate recirculation applied in bioreactor landfills to eliminate ground water contamination [37]. Simultaneously, the proportion of methane in landfill gas is higher with leachate recirculation than those without recirculation. In a lysimeter study, biogas obtained was characterized by the highest concentration of methane i.e. 50 % [13].

The effects of leachate recirculation are more effective in anaerobic reaction than in aerobic reaction [7]. According to Reinhart and Townsend, [33] leachate recirculation enhances the efficiency of anaerobic digestion by providing moisture.

Lettinga and Van Haandel, [26] identified four stages for the transformation of complex compounds into biogas in an anaerobic processs:

1. Hydrolysis stage: In this stage, complex compounds are hydrolysed into dissolved compounds with a low molecular weight. Protein is degraded to amino acid, carbohydrate is transformed to monosaccharides and disaccharides and lipid are converted to long-chain fatty acid.
2. Acidogenesis stage: simple organic compound such as volatile fatty acid, alcohol, lactic acid and mineral compounds such as carbon hydroxide, hydrogen, and ammonia and hydrogen sulphide are formed from the dissolved compounds
3. Acetogenesis stage or fermentation: The products from acidogenesis stage are converted to suitable substrate of methanogen microorganism such as acetate, hydrogen and carbon dioxide.
4. Methanogenesisstage: It is the limiting step of anaerobic digestion. In this step, hydrogenotrophic bacteria converts carbon dioxide and hydrogen to methane and methanogenic bacteria converts acetate to methane.

Effect of leachate recirculation on organic compound removal

Leachate recirculation showed significantly rapid degradation and quicker stabilization of waste than those without recirculation due to decrease in time period taken by acidogenesis and methanogenes phases [14, 10]. Sawatdeenarunat, 2009 observed that due to the accumulation of carboxylic acid there was an increase in COD and BOD in the first 2 years after recirculation and then a decrease in 3rd year.

Effect of leachate recirculation on metal concentration

As suggested by Reinhart and Townsend, 1997 "the balance of biological process of waste degradation and the hydrologic capacity of the waste which controlled by the waste permeability" is the major factor for leachate treatment. Bilgili *et al*., [7] studied the effect of leachate recirculation on metal concentrations of a simulated landfill. According to Bilgili *et al*., [7] metal sulfide and metal hydroxide precipitation and subsequent capture within the waste matrix by encapsulation, sorption, ion-exchange and filtration appear to be the primary mechanisms of metal removal of bioreactor landfills. In the acidogenensis stage pH of leachate is low (4.0– 6.0), so the metals dissolve into leachate due to high solubility. The results show that after an initial increase, the concentrations of metal decrease about 50% in 250 days. Gould *et al*., 1989 in a lysimeter study found that leachate recirculation simulated reducing condition and so cause reduction of sulfate to sulfide which causes low concentration of leachate. In addition, high molecular weight humic-like substances are formed and tend to form complex with heavy metal [32]. Benson *et al*., [6] studied the landfill gas production rate and showed that the gas flow rate from bioreactor landfill was 69% higher than landfill without leachate recirculation. Sawatdeenarunat, [37] indicated that due to stimulation of hydrolytic and fermentative bacteria by leachate recirculation, pH tended to increase for about one year. After that, pH increased and become stable between 7.0 and 8.0 due to methanogenesis stage. Leachate recirculation creates a favourable environment for rapid microbial decomposition of the biodegradable solid waste.

Bioreactor landfill v/s conventional landfill

As depicted in table 1, Reinhart and Al-Yousfi, [32] compared the leachate characteristics between bioreactor landfill and conventional landfill. Due to the moisture content in bioreactor landfill the strength of leachate of bioreactor is less than conventional landfill. Results show that in bioreactor landfill BOD ranges from 12-28000mg/l while it ranges from 20-40000 mg/l in conventional landfill. Similarly, COD for bioreactor landfill was 20 – 34,500mg/l while it was 500 – 60,000 mg/l for conventional one. In a similar study by Reinhart and Townsend, [33], the concentration of leachate constituents was measured in both types of landfills in sequential phases. Highest strength of leachate was noticed in acid formation phase than other phases. The quantities of Iron (Fe) and Ammonia (NH_3) were 20 – 2,100 mg/l and 30 – 3,000 mg/L in conventional and 4 – 1,095 mg/l and 6 – 1,850 mg/l in bioreactor landfill.

Benefits of Leachate Recirculation

According to Khire, 2006 key benefits of leachate recirculation in MSW landfills are (1) reduction in leachate treatment and disposal costs; (2) accelerated decomposition and settlement of waste resulting in gain in airspace; (3) acceleration in gas production; and (4) potential reduction in post-closure care period and associated costs.

Most common methods for long-term leachate recirculation in MSW landfills include vertical injection wells and horizontal trenches. Non-uniform distribution of leachate leads to uneven landfill settlement and hence higher maintenance costs. According to study by Fellin *et.al*., [15] leachate recirculation benefits the landfill by increasing the moisture content which in turn increases the rate of biological degradation in the landfill, and the rate of methane, nitrogen and carbon recovery from the landfill as depicted in Table 1.

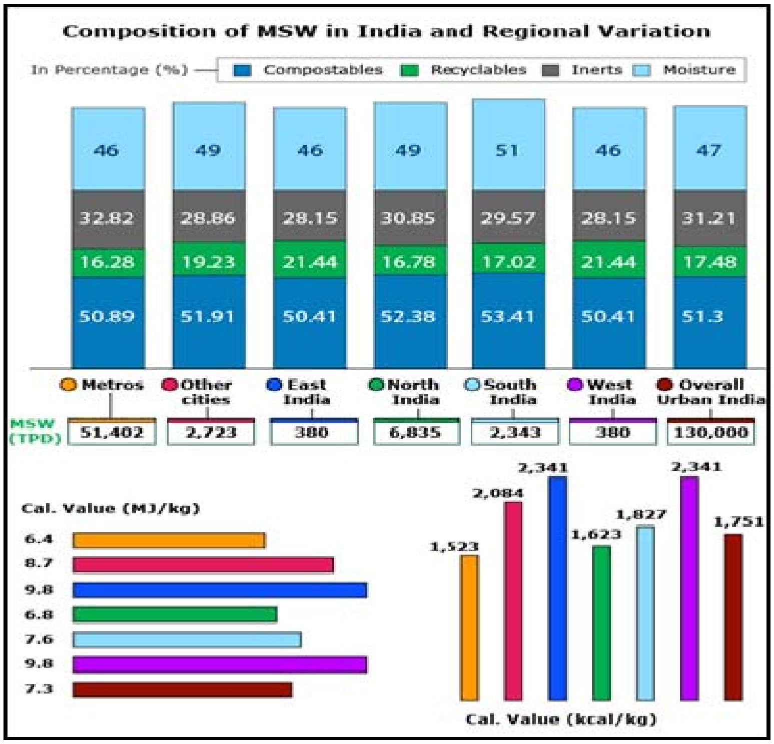
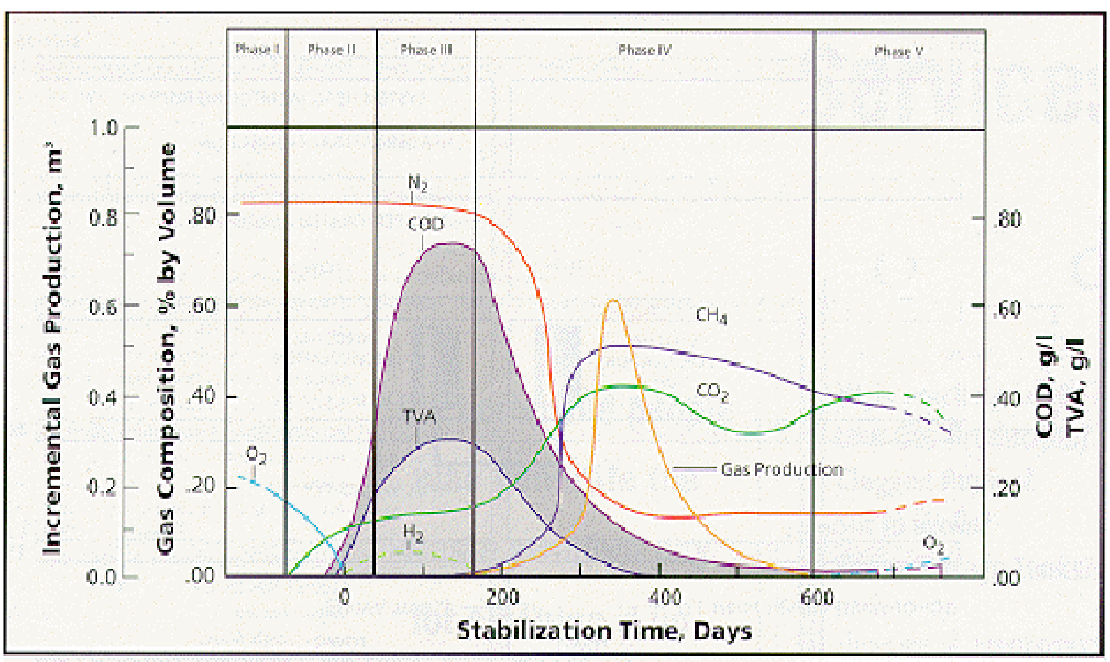


Figure 1: Composition of MSW in India and regional variation.

Source: Sustainable solid management in India, 2012,Ranjith Kharwal Annepu



(Pohland and Harper, 1986) "Landfill Bioreactor Design and Operation" by Rhinehart and Townsend

Figure 2: Phases of MSW decomposition and stabilization

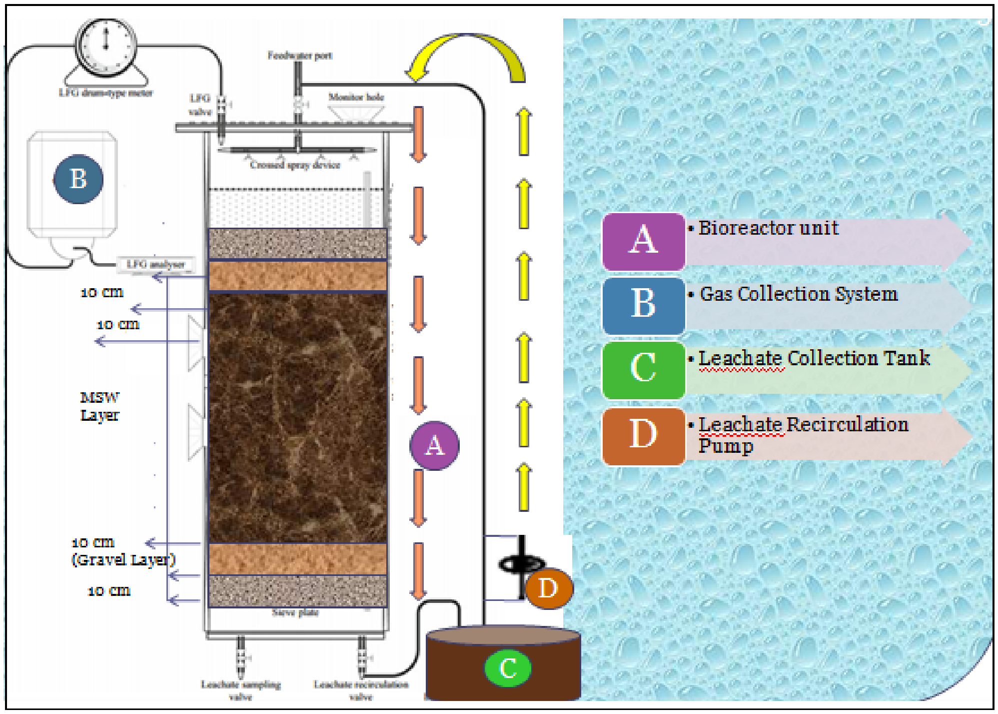


Figure 3: The Design of a typical bioreactor

Table 1: Effect of leachate recirculation on Bioreactor landfill v/s conventional landfill

Parameter	Phase II. Transition		Phase III. Acid formation		Phase IV. Methane fermentation		Phase V. Final maturation	
	Conventional	Recirculation	Conventional	Recirculation	Conventional	Recirculation	Conventional	Recirculation
BOD (mg/L)	100 - 1,000	0 – 6,893	1,000 - 57,700	0 – 28,000	600 -3,400	100 - 10,000	4 - 120	100
COD (mg/L)	480 - 18,000	20 – 20,000	1,500- 71,000	11,600- 34,550	580 - 9,760	1,800 - 17,000	31 - 900	770 - 1,000
TVA (mg/L as acetic acid)	100 - 3,000	200 – 2,700	3,000- 18,800	0-30,730	250 - 4,000	0 - 39,000	0	-
BOD/COD	0.23 - 0.87	0.1 – 0.98	0.4 - 0.8	0.45 - 0.95	0.17 - 0.64	0.05 - 0.8	0.02-0.13	0.05 - 0.08
NH_4 (mg/L-N)	120 - 125	76 - 125	2- 1,030	0-1,800	6 - 340	32 - 1,850	6 - 430	420 - 580
pH	6.7	5.4 – 8.1	4.7 - 7.7	5.7-7.4	6.3 - 8.8	5.9 - 8.6	7.1 - 8.8	7.4 - 8.3
Conductivity (mS /cm)	2,450 - 3,310	2,200 – 8,000	10,000- 17,100	10,000- 18,000	2,900 - 7,700	4,200 - 16,000	1,400 - 4,500	-

CONCLUSION

The bioreactor landfill technology is based on the acceleration of the anaerobic degradation of the biodegradable fraction of the wastes leading to faster mineralization and hence stabilization. It uses enhanced microbiological processes to transform and stabilize the readily and moderately decomposable organic waste constituents. From this review it has been drawn that a leachate recirculating bioreactor efficiently stabilizes the waste mined from dumpsite by enhancing organic degradation. Engineered bioreactor landfill sites can provide a more controlled way which society can reduce the emission of global warming greenhouse gases. The Conclusions from the cited literature in the review depicts a reduction in leachate organics, decrease in leachate's BOD, COD, ratio of BOD/COD, VSS/TSS, TKN along with the VFA profile, achieved through leachate recirculation. These are used as indicators to assess the efficiency of the bioreactor. Best results were achieved by leachate recirculation along efficiently immobilization of heavy metals in the digested residue as observed from the low heavy metal levels in leachate. To conclude, "Bioreactors act like filters, enabling a separation of the nutrients from municipal solid waste encouraging rapid waste stabilization". Still there is a need to undertake further studies to reduce our current gaps-in-knowledge and offer feasible technical alternatives to control and steer the processes occurring in a reactor.

REFERENCES

[1] Agnew, J., Sampson, C., Gaudet M. 2013. Solid-State Anaerobic Digestion in the Canadian Prairies—Pilot Scale Study. The Canadian Society for Bioengineering. University of Saskatechewan, CSBE: 13-021.
[2] Ahn, D.H., Chung, YC., Chang, WS. 2002. Use of coagulant and zeolite to enhance the biological treatment efficiency of high ammonia leachate. J. Environ. Sci. Health, 37, pp. 163-173.
[3] Annepu, R.K. 2012. Sustainable solid waste management in India. Dissertation, Columbia University, New York
[4] Barlaz, M.A., Ham, R.K., Schaefer D.M. 1990. Methane production from municipal refuse: a review of enhancement techniques and microbial dynamics. CRC Critical Rev Environ Control, 19(3), pp. 557–584
[5] Behzad, N., Saied, P., Elmira, S. 2011. Investigated Environmental Management for Landfill Leachate. Research Journal of Chemistry and Environment, 15 (2), pp. 1-3.
[6] Benson, C.H., Barlaz, M.A., Lane, D.T., Rawe, J.M. 2007. Practice review of five bioreactor/recirculation landfills. Waste Management, 27, pp. 13-29
[7] Bilgili, M.S., Demir, A., Özkaya, B. 2007. Influence of leachate recirculation on aerobic and anaerobic decomposition of solid wastes. Journal of Hazardous Materials, 143, pp. 177-183.
[8] Bohdziewicz, J., Bodzek, M., Gorska, J. 2001. Application of Pressure driven membrane techniques to biological treatment of landfill leachate. Process Biochemistry, 36(7), pp. 641-646.
[9] Bookter, T.J., Ham, R.K. 1982. Stabilization of solid wastes in landfills. J. Environ. Eng, 108 (6): 1089-1100.
[10] Chan, G.Y.S., Chu, L.M., Wong, M.H. 2002. Effect of leachate recirculation on biogas production from landfill codisposal of municipal solid waste, sewage sludge and marine sediments. Environ. Pollution, 118: 393–399. 36, pp. 641-646.
[11] Eric, S. 1990. Microbiology of Landfill sites. CRC Press Inc ISBN 0-8493-4996-6.
[12] Erses, S., Onay, T.T. 2003. In situ heavy metal attenuation in landfills under methanogenic conditions. J. Hazard. Mater 99, pp. 159-175
[13] Filipkowska, U. 2007. Effect of Recirculation Method on Quality of Landfill Leachate and Effectiveness of Biogas Production. Department of Environmental Sciences and Fisheries, University of Warmia and Mazury in Olsztyn, Poland. Polish J. of Environ. Stud., 17 (2), pp. 199-207
[14] Francois, V., Feuillade, G., Matejka, G., Lagier, T., Skhiri, N. 2007. Leachate recirculation effects on waste degradation: Study on columns. Waste management 27, pp. 1259-1272
[15] Fellin, P., Barrie, L.A., Dougherty, D., Toom, D., Muir, D., Grift, N., Lockhar, L., Billeck, B. 1996. Air monitoring in the arctic: results for selected persistent organic pollutants. Environ. Toxicol. Chem 15, pp. 253-261.
[16] Gawalpanchi, R.R., Mhaisalkar, V.A., Hiraou, S., Bhide, A.D. 2007. Treatment of leachate by recirculation through a bio-reactor proceedings of the International Conference on Sustainable Solid Waste Management, Chennai, India, pp. 460-465
[17] Gould, J.P., Cross, W.H., Tedder, D.W., Pohland, F.G. 1989. Factors influencing mobility of toxic metals in landfills operated with leachate recycle. In Emerging Technologies in Hazardous Waste Management, ACS Symposium Series 422.
[18] Gurijala, K.R., Suflita, J.M. 1993 Environmental factors influencing methanogenesis from refuse in landfill samples. Environ. Sci. Technol 27(6), pp. 1176-1181.
[19] Hogland, W., Visvanathan, C., Marques, M., Manandhar, D.R. (2005) Landfill in Asia Improving sanitation of landfill sites. Waste Management World 2, pp. 87-96
[20] Karthikeyan, O.P., Swati, M.R., Joseph, N.K. 2006. Performance of bioreactor landfill with waste mined from a dumpsite. Environ Monit Assess, 135, pp. 141–151
[21] Karthikeyan, O.P., Kurian, J., Nagendran, R. 2007. Leachate Recirculation to Reducethe Pollution Potential Of Waste Mined from Open Dumpsite – ALysimeter Study. Proceedings Sardinia, Eleventh International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy.
[22] Khim, N. 2007. Assessment of aeration and leachate recirculation in open cell landfill operation with leachate management strategies. A thesis, Asian Institute of Technology School of Environment, Resources and Development, Thailand.
[23] Khire, P.E. 2005. Field-scale testing of leachate recirculation blankets made up of recycle tires. Available online: http://www.egr.msu.edu/cee/research/environmental/. Date retrieved: July.07, 2012.
[24] Kjeldsen, P., Barlaz, M.A., Rooler, A.P., Baun, A., Ledin, A., Christensen, T.H. 2002. Present and long-term composition of MSW landfill leachate. A review. Critical Review in Environmental Science and Technology 32, pp. 293-336
[25] Leckie, J.O., Pacey, J.G., Halvadakis, C.1979. Landfill management with moisture control. Journal of the Environmental Engineering Division, ASCE 105, pp. 337-355.
[26] Lettinga, G., Van Haandel, A.C. 1990. Anaerobic Sewage Treatment, John Wiley & Sons, New York. Water Science and Technology 44(6), pp. 181-188.

[27] Maloney, S. (1986). Sanitary Landfill Leachate Recycle and Environmental Problems at Selected Army Landfill: Lessons Learned, US Army Corps of engineers, Tech Report N, 86 (17).
[28] Manandhar, D.R. 2000. Water management in sanitary landfills in tropical countries. Journal of Environmental Engineering, 128(3), pp. 228–236
[29] Manandhar and Trankler J. 2005. Influence of tropical seasonal variations on landfill leachate characteristics Results from lysimeter studies. Waste management 25, pp. 1013-1020.
[30] Pacey, J., Augestein, D., Morck, R., Reinhart, D., Yazdani, R. 2000. The bioreactor landfill an innovation in solid waste management. MSW management 2, pp. 53– 60.
[31] Pouech, P., Galtier, L, Labbe, H., Carles, L and Gerbaux O. 1999. Leachate Recirculation Control in an Extensive Bioreactor Landfill. In Sardinia 99, Proceedings of the 7th International Landfill Symposium, Cagliari, Italy.
[32] Reinhart, D.R and Al-yousfi A.B. 1996. The impact of leachate recirculation on municipal solid waste landfill operating characteristics. Waste Management Res. 14, pp. 337-346.
[33] Reinhart, D.R and Townsend T.G. 1998. Landfill Bioreactor Design and Operation. Lewis Publishers, Boca Raton, NY. CDFS 139-05.
[34] Reinhart, D.R., McCreanor, P.T and Townsend T.G. 2002. The bioreactor landfill: Its status and future. Waste Management Res. 20, pp. 172-186.
[35] Rout, C. 2010. Municipal Solid Waste Stabilisation by Leachate Recirculation. A case study of Ambala City, International journal of environmental sciences 1(4), pp. 645 - 655
[36] San, I and Onay, T.T. 2001. Impact of various leachate recirculation regimes on municipal solid waste degradation. Journal of Hazardous Materials 87, pp. 259-27
[37] Sanawatdeenarunat, C. 2010. Effects of leachate recirculation on anaerobic treatment of municipal solid waste. Presented at 3rd international conference on geoinformation technology for natural disaster management & rehabilitation 4(1), pp. 448.
[38] Tatsi, A.A and Zouboulis, A.I 2002. A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean climate (Thessaloniki, Greece). J. Advances in Environmental Research 6, pp. 207-219
[39] Tchobanoglous, G., Hilary, T and Samuel V. 1993. Integrated Solid Waste Management: Engineering Principles and Management Issues. San Francisco, Irwin McGraw-Hill.
[40] Tsao, G.T. 1984. Bacterial Hydrolysis- A review anaerobic digestion and carbohydrate hydrolysis of waste-proceedings of the information symposium under the EEC programme on recycling of urban and industrial waste, Luxemberg. Elsevier applied science publishers ISBN 0-85334-324-1
[41] Vaidya, R.D. 2002. Solid waste degradation, compaction and water holding capacity. A Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
[42] Visvanathan, C., Tränkler, J, Basnayake., Chiemchaisri, C., Joseph, K and Gonming Z .2003. Landfill management in Asia-Notions about future approaches to appropriate and sustainable solutions. Proceedings Sardinia. Ninth International Waste management and Landfill Symposium, Cagliari, Italy.
[43] William, Z.H., Visvanathan, C., Marcacia, M and Dinesh R.M. 2005. Landfill in Asia. ELFM symposium. paper 12.
[44] Yao., Kong, Q., Li, W., Zhu, h., Shan, D.S. 2013. Effect of leachate recirculation on migration of copper and zinc in municipal solid waste and municipal solid waste incineration bottom ash codisposed landfill. Springerlink ISBN- 10163-013-0217-7.