

# Bioreactor Landfill Technology

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**Abstract:** From a future perspective, the ways of Municipal solid waste management in India has to be improved for a better quality of life. Open dumping or landfilling is adopted as the ultimate means of disposal in India. It is considered as a cost effective method, if sufficient land is available. Over the years, apart from some improvements such as recycling and source reduction techniques, it can be found that landfill disposal of waste will remain as an unavoidable element of the solid waste management system. The concept of a Bioreactor landfill technology for Indian Municipal solid waste management is studied in this paper. Bioreactor landfill concept changes the purpose of landfilling from storage to treatment of waste. The working principle is that the bioreactor landfills promotes and accelerates the biological degradation of the organic fraction of the incoming waste by maintaining optimum moisture content inside the cells where the wastes are stored. Moisture can be controlled by the recirculation of leachate and the organic waste gets stabilized by the microbes. Significant environmental and economical benefits can be derived by the installation of Bioreactor landfills, and can be considered as a promising technique of solid waste management system for a highly populated and developing country like India.

**Keywords:** Bioreactor landfill; landfilling; recycling; source reduction; municipal solid waste; degradation; recirculation; environmental benefit.

## 1. Introduction

A bioreactor landfill is an engineered landfill, which promotes enhanced microbiological activity to decompose and stabilize the incoming organic fraction of the municipal solid waste within a period of 5 to 10 years of implementation. Maintaining of optimum moisture content by leachate recirculation is considered to be an essential part of this technology. Other factors that increases the efficiency of this system includes the shredding of the incoming waste, nutrient addition, pH adjustment, waste pre-disposal and post-disposal conditioning, and temperature control [10]. Also the potential of this landfill, if anaerobic microbes are introduced for waste stabilization, to generate methane gas classify this also as a waste to energy technology.

About 960 million tonnes of solid waste is being generated in India every year [1]. This data shows that around 2.63 million tonnes of waste is being produced in India per day. Such a huge amount of Solid waste needs to be disposed off efficiently by a proper solid waste management system. From a study conducted by [1], it can be inferred that from waste to energy techniques, a total of around 2000 kg of Delhi municipal solid waste (MSW) produced around 700 tonnes of methane gas per day. The methane produced is an energy source and can replace petrol for refueling vehicles, coal for heat and energy production and natural gas for municipal gas supply. So the installation of Bioreactor landfills for the treatment and disposal of MSW in India could prove to be a boom in the Indian economy too.

## 2. Types of Bioreactor Landfills

The bioreactor landfills can be classified into three types based on their working mechanism. Aerobic, Anaerobic and Hybrid Bioreactor landfills [6].

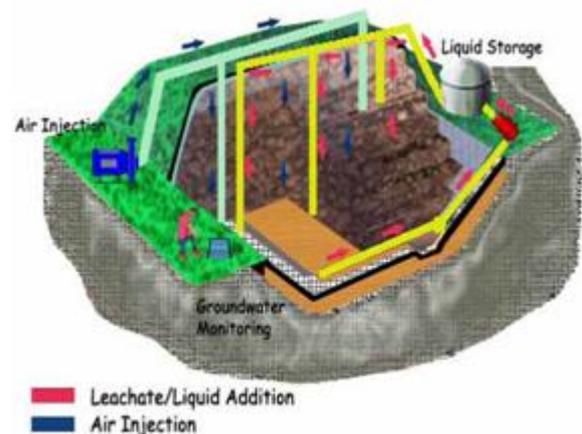


Figure 1: Aerobic Bioreactor landfill [10].

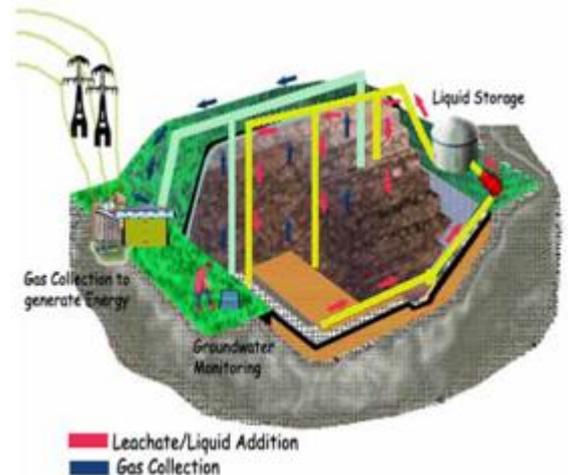


Figure 2: Aerobic Bioreactor landfill [10].

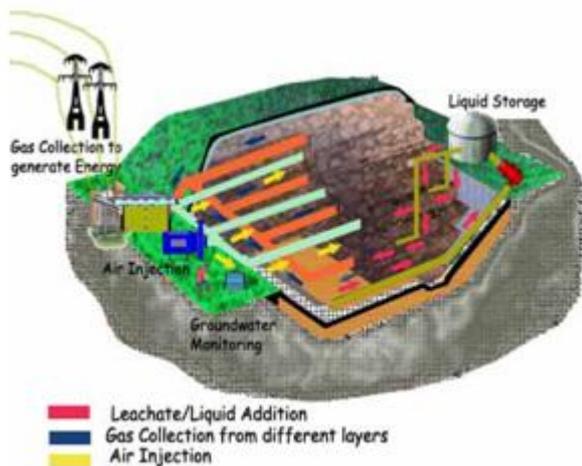


Figure 3: Hybrid Bioreactor landfill [10].

**Aerobic Bioreactor landfills:** In this system, the leachate that oozes out of the waste are collected and recirculated with other liquids for attaining optimum moisture levels. Aerobic bacteria prevails inside the system and so air is also injected into the waste mass along with the fluids to accelerate the aerobic decomposition of bacteria in the solid wastes. Here horizontal or vertical wells are used for air injection into the system.

**Anaerobic Bioreactor landfills:** In this system, the optimum moisture levels are attained same as in the aerobic system, by recirculation of the fluids. But, since the system is anaerobic and anaerobic decomposition of solid waste exists in the system, air is not injected here. Anaerobic biodegradation occurs by anaerobic bacteria in the absence of oxygen. Methane (CH<sub>4</sub>) and Carbon dioxide (CO<sub>2</sub>) gases, commonly known as the landfill gases (LFG) can be collected from this system. An anaerobic bioreactor landfill gives the advantage of energy production as well as minimizing of Green house gas emission.

**Hybrid Bioreactor landfills:** These are also known as the Aerobic-Anaerobic bioreactor landfills. This system supplies air to the upper layers of the waste mass as in the aerobic reactor, while the gas collection can be attained from the lower layers. Since aerobic degradation is a faster technique, it decomposes the organic solids in the upper layers rapidly. Thus the onset of methanogenesis takes place rapidly in this system, which is a great advantage.

### 3. Pros and Cons of a Bioreactor landfill

The advantages of a bioreactor landfill over a simple dry tomb landfill are plenty.

- Rapid settlement of wastes takes place in this setup and so the whole volume gets reduced and stabilized within in 5-10 years, after the implementation of the bioreactor landfill.
- The Improved leachate quality is not an environmental concern and gets stabilized within 3 years of closure of the landfill.
- The land can be reused as soon as the closure of the landfill.
- Huge economic benefit due to large amount of gas generation over short period of time.

- Increased GHG emission reduction.
- Increased effective density of landfill. More wastes can be placed into the landfill space.
- The recirculation of leachate within the reactor benefits from the cost of treatment and disposal of leachate as in a normal landfill [3].

However there are some uncertainties for this technology which holds as some of its drawbacks.

- Confusion over existing regulations to permit bioreactors
- The initial cost of investment is high as this is an engineered landfill. Many networks for leachate and air injection has to be constructed which raises the capital cost.
- High operating skills for labours is required as control of this bioreactor determines its efficiency.
- Temperature control in aerobic bioreactors is a very important factor.
- Geotechnical stability
- Liner chemical compatibility
- Odour control
- Availability of liquids [3].

But most of these drawbacks listed above may be reduced, if the bioreactors are well controlled and monitored frequently. Moreover by course of time the bioreactor landfill becomes a source of economy.

### 4. Concept of a Bioreactor landfill

#### Essential components of the system

- 1) A liner system at the base and sides of the landfill
- 2) A leachate collection and control facility
- 3) A gas collection system and control facility (optional for small landfills)
- 4) A final cover at the top of the landfill.
- 5) A surface water drainage system
- 6) An environmental monitoring system
- 7) A closure and post-closure plan [5]

#### Design elements

The required design elements include:

- 1) Liner systems (using low permeability material such as natural clay or manmade geo-membranes)
- 2) Leachate collection and removal systems
- 3) Gas collection and control systems
- 4) Surface water controls
- 5) Access roads
- 6) Structures, including administration building and scale house
- 7) Utilities
- 8) Fencing
- 9) Wash racks (to remove dirt from truck tires)
- 10) Groundwater and landfill gas monitoring
- 11) Landscaping [6]

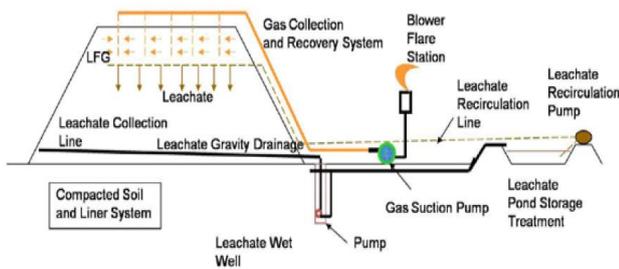


Figure 4: Major components of an anaerobic bioreactor landfill [6].

**Liners:** Liners prevent the seepage of leachate to the subsurface soil layers thus preventing the contamination of ground water. The different types of liners are single composite liners, single non-composite mixed composite liners, and double liner systems with leak detection systems. [6]. A composite liner consisting of a geomembrane and a clay layer is used in convectional landfills. A double composite liner system may also be used, which further prevents the escape of leached leachate to the environment [2].

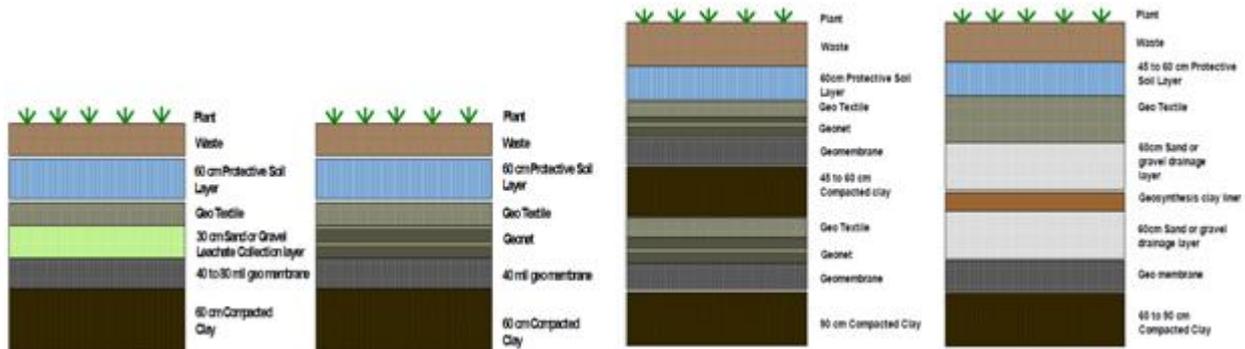


Figure 5: Composite liner and Double composite liner [2].

**Leachate collection system:** The leachate collection system should be designed carefully and efficiently to collect, remove and manage leachate. It should be designed such a way that it can collect higher volume of water, as recirculation is being practiced in bioreactor landfills i.e., the size of the pipe or the pumping capacity will be greater than in case of convectional landfills. In case of enhanced biodegradation activity, there are chances for the fine particles to clog and so the filter and operational layers should be designed around the leachate collection pipe system [14].

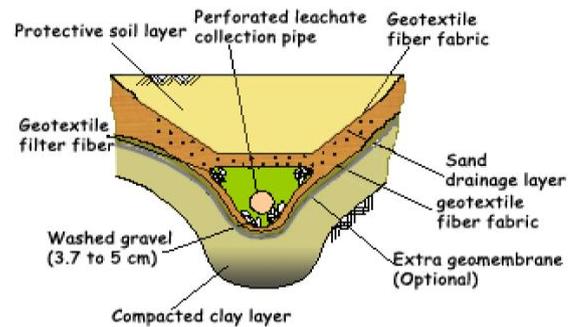


Figure 6: Schematic of leachate collection system [2].

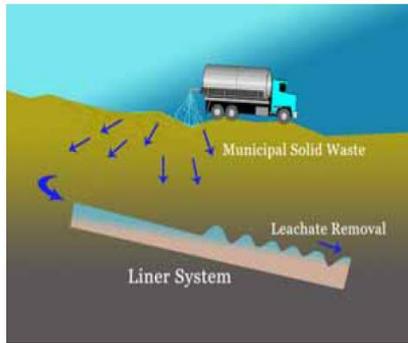
The remaining leachate that is stored after recirculating should be drained out to maintain a hydraulic head within the landfill, 30cm or less. If the leachate cannot move out, it will leak out of the landfill and contaminate the environment [2].

**Leachate distribution system:** In case of bioreactors, the distribution system can be classified as five types as shown in the table 1.

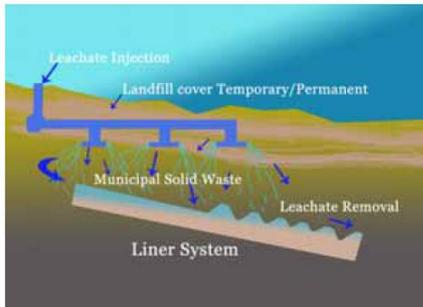
Table 1: Leachate distribution System [10]

Method	Description	Remark
Prewetting of waste	Using fire hose from water tankers or manual spraying.	This technique has been rarely used in large scale operation because of its labor-intensive nature.
Leachate spraying	Using sprinkler.	Some states have banned it
Surface pond	Using surface infiltration pond above lift of solid waste.	Ponds collect storm water and can be a source of odors.
Vertical injection wells	Using pumping or gravity force to release leachate flow.	This is the most popular method.
Horizontal subsurface introduction	Using pumping or gravity force.	

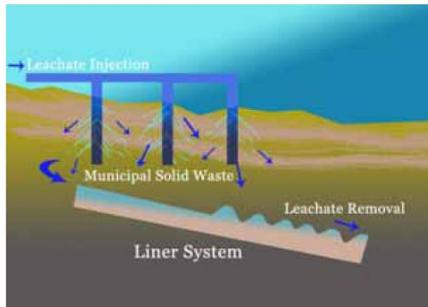
The environmental impacts, climatic factors, worker exposure, evaporation loss, reliability, uniformity and aesthetics are considered in deciding the type of distribution system to be selected [2].



**Figure 7:** Surface distribution directly on waste [14].



**Figure 8:** Distribution beneath cover using manifold system [14].

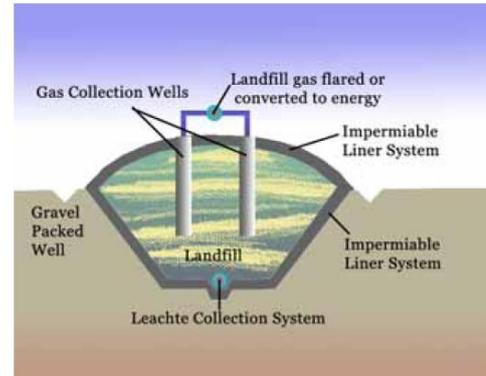


**Figure 9:** Injection from within vertical wells [14].



**Figure 10:** Vertical Wells [14].

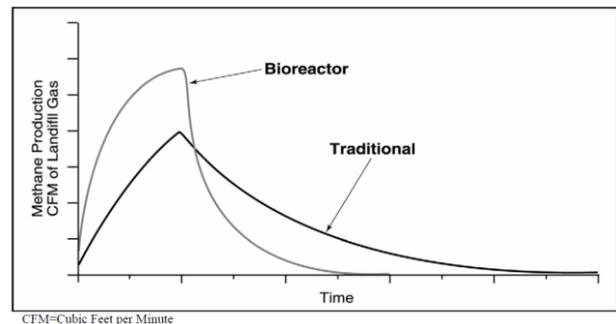
**Landfill Gas collection system:** The accelerated decomposition of waste in the bioreactor landfills makes it mandatory that the gas collection system should be installed from the early phase of the landfill operation. As the height of landfill increases, a horizontal gas collection system can be provided at a later stage [2].



**Figure 11:** Landfill Gas collection system (ARRPET., 2004).

**Landfill gas production in Convectional landfills and Bioreactors**

Landfill gas (LFG) is a by-product of anaerobic waste decomposition in Anaerobic bioreactor landfills. The landfill gas mainly comprises of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). A typical landfill gas will have more CH<sub>4</sub> than CO<sub>2</sub>. The other fraction includes traces of water vapor, hydrogen sulfide and a variety of organic chemicals, are also found in LFG [12].



**Figure 12:** Typical Landfill Gas prediction curve for a convectional landfill and a Bioreactor [6].

The figure clearly shows that the bioreactor generates LFG from the early phase of the landfill operation as compared to a conventional landfill. It is also evident that the rate of LFG generation is also high and for a shorter period of time in case of a bioreactor landfill. From this it can be inferred that maximum LFG generation occurs at the active life period in a bioreactor landfill. Also this increases the feasibility of cost effective LFG recovery and to minimize fugitive emissions. The other advantage in case of this technology is that the landfill site can be reused for other purposes within a period of 5-10 years after the closure of the landfill. This time period can extend upto 30 to 50 years in case of a convectional landfill. In a study conducted by [6], if 50% of the MSW currently being landfilled in U.S could be treated in a controlled bioreactor landfill, it could produce LFG volume that could meet more than 1% of the total US electrical needs.

**Daily, Intermediate and Final Cover Soils:** In a convectional landfill, design of cover soil has been oriented towards selecting material that will not create an impermeable layer to impede the leachate's downward movement, nor restrict gas capture [3]. Here the daily cover refers to the 150 mm of soil layer placed above each lift of wastes. But, in Bioreactor landfills, these covers prevent the leachate from escaping through the sides of the landfill and contaminate the environment. This cover over the wastes also have an advantage of safety against diseases, vectors, fires, odors, blowing litters, and scavenging without presenting a threat to human health and the environment [2].

The alternative cover may be compacted with agricultural wastes such as composted yard wastes, etc. These materials degrade and can be placed over the solid waste lifts. Other alternative cover materials include polymer foams, slurry sprays, sludge, reusable geosynthetics and geotextile. The geotextile has a higher advantage compared to these other materials. i.e. It can control the rate of precipitation and infiltration into the landfill. For bioreactor landfills, a final cover may not be placed until most of the settlement has occurred. Instead, a temporary cover may be placed [2].

**Monitoring of Bioreactor Landfills:** Monitoring and proper recordkeeping is very important at all landfills, but in case of bioreactor landfills it is highly critical and should be accurate as the entire efficiency of this system depends on how well it is controlled. Most bioreactor landfills have operators who are responsible for routine data collection and reporting. Keeping proper records of the liquid balance in the cells, the liquids added to the landfill and leachate removed from the landfill should be a major emphasis [12].

Also, the staff responsible for Bioreactor Landfill Operation should be experienced and well trained and has multiple responsibilities. These responsibilities include the operation of liquids addition in the system, inspection of the landfill site, and recording of necessary data. In many cases these operators will also play a large role in managing the gas collection system. Another role of the staff is to monitor carefully and to do the appropriate maintenance works when ever needed, mainly in case of the fluid handling systems such as the pumps and meters [12].

## 5. Conclusion

It's now time to think for the future and seriously consider waste management as a major concern for a developing country like India. The huge amount of solid waste that is being produced in India and the depreciation of the Indian economy could be solved together by promoting this Bioreactor landfill technology as a major treatment methodology in waste management. A full scale application of Bioreactor technology can relatively stabilize the whole waste within 5 to 10 years, as compared to many decades in case of dry tomb landfills. Thus it also opens a wide range of possibilities for the reuse of land, resources and property, after the lifetime of the landfill. It is hoped that this technology will become an effective option in managing our solid waste industry in the near future.

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