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Municipal Solid Waste Management by Sanitary Landfill

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Abstract

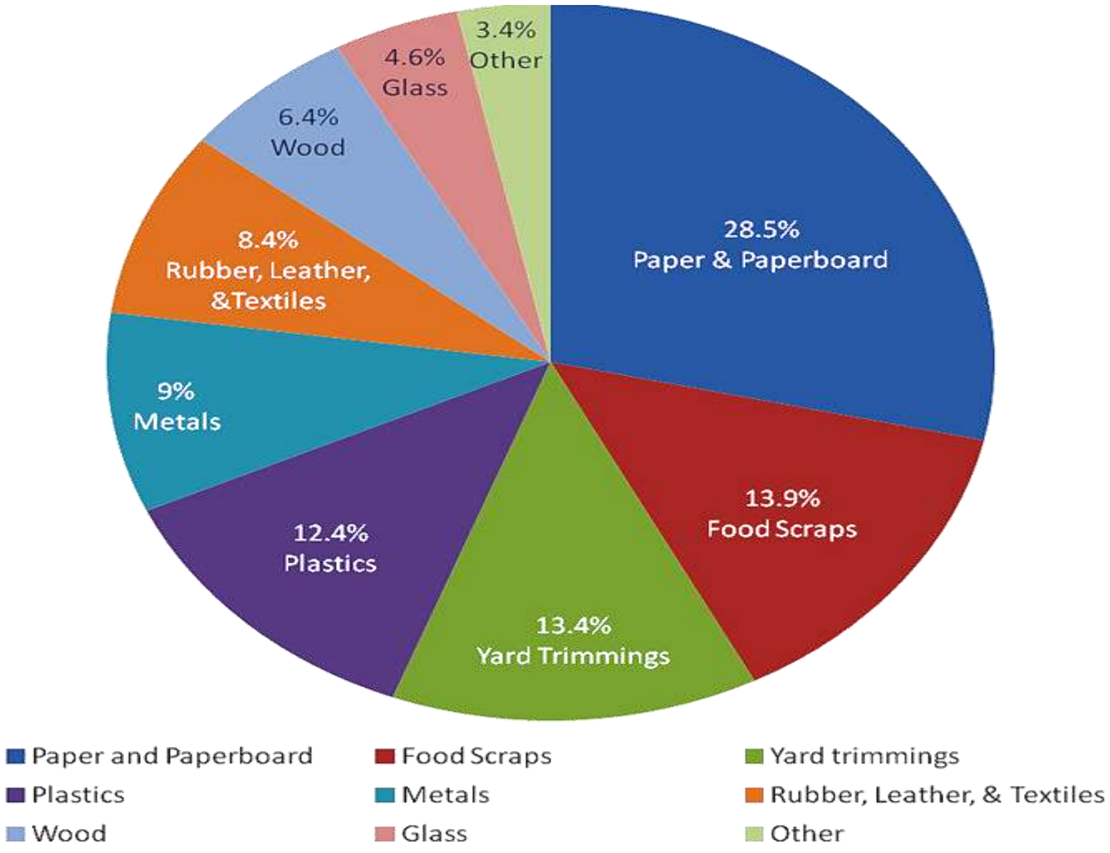
Attending sustainability in waste management require an option that employs environmental friendliness. The generation of municipal solid waste is increasing year by year and there are many options for handling and disposing these wastes. Major environmental concerns of municipal landfills revolve around quantity and quality of leachate, gas generation, and decomposition processes occurring therein. Minimizing the time period for maximum biodegradation to reduce leachate and gas emissions after landfill closure, ease the requirement of leachate treatment, and reclamation of landfill site. In this context, several enhancement techniques are being implemented to increase the biological activity in the landfills. As early as 1970, researchers started exploring the potential of applying leachate recirculation in landfills to enhance the stabilization of waste and generation of landfill gas. This paper reviews the benefits of bioreactor landfill operation techniques with the conventional landfill techniques from past and ongoing field trials and culminates with the need for the research on the promising technology in India.

Keywords: Municipal Solid Waste (MSW), landfill, leachate and biogas.

Introduction

Due to rapid population growth and economic development, there has been a significant increase in municipal solid waste (MSW) generation in India. The estimated solid waste generation in India ranges from 100g per capita per day in small towns, 300-400g per caipta per day in medium cities and about 500g per capita per day in large cities. As per the available trend the amount of waste generated per capita is estimated to increase at a rate of 1% – 1.33% annually Sustainable development was defined in 1987, in the report of the World Commission on Environment and Development, as development which meets the needs of the present without compromising the ability of future generations to meet their own needs. Landfill has been defined as the engineered deposit of waste onto and into land in such a way that pollution or harm to the environment is prevented and, through restoration, land provided which may be used for another purpose. In general term a sustainable landfill described as a landfill designed and operated in such a way that minimizes both short-term and long-term environmental risks to an acceptable level Over the past ten years, experimental testing and field, pilot studies have been conducted to develop and improve landfill techniques and designs to enhance solid waste degradation such as reducing the time period of leachate treatment, increasing methane production, accelerating the subsidence of waste, thus permitting air space recovery and reduction of contamination life span. Techniques used to enhance the degradation process are leachate recirculation and addition of nutrients and sludge. Increasing attention is being given to leachate recirculation in landfill bioreactors as an effective way to enhance the microbial decomposition of organic fraction of municipal solid waste. Such systems are operationally influenced to promote synergy between the inherent microbial consortia and controlled to accelerate the sequential phase of waste stabilization, primarily reflected by characteristics changes in quantity and quality of leachate and gas production. Numerous landfill investigation studies have suggested that stabilization of waste proceeds in five sequential and distinct phases. The rate and characteristics of leachate produced and biogas generated from a landfill vary from one phase to another, and reflect the microbially mediated processes taking place inside the landfill. The below figure gives the idea of how much solid waste is generated roughly.

Total municipal waste generated by material wise



Basic requirements

As a minimum, four basic conditions should be met by any site design and operation before it can be regarded as a sanitary landfill:

- Full or partial hydrogeological isolation: if a site cannot be located on land which naturally contains leachate security, additional lining materials should be brought to the site to reduce leakage from the base of the site (leachate) and help reduce contamination of groundwater and surrounding soil. If a liner - soil or synthetic - is provided without a system of leachate collection, all leachate will eventually reach the surrounding environment. Leachate collection and treatment must be stressed as a basic requirement.
- Formal engineering preparations: designs should be developed from local geological and hydrogeological investigations. A waste disposal plan and a final restoration plan should also be developed.
- Permanent control: trained staff should be based at the landfill to supervise site preparation and construction, the depositing of waste and the regular operation and maintenance.
- Planned waste emplacement and covering: waste should be spread in layers and compacted. A small working area which is covered daily helps make the waste less accessible to pests and vermin.

The phases experienced by degrading wastes are described below.

I: Initial adjustment **-** This phase is associated with initial placement of solid waste and accumulation of moisture within landfills. An acclimation period (or initial lag time) is observed until sufficient moisture develops and supports an active microbial community. Preliminary changes in environmental components occur in order to create favourable conditions for biochemical decomposition.

II: Transition **-** In the transition phase, the field capacity is sometimes exceeded, and a transformation from an aerobic to anaerobic environment occurs, as evidenced by the depletion of oxygen trapped within a landfill media. A trend toward reducing conditions is established in accordance with shifting of electron acceptors from oxygen to nitrates and sulphates, and the displacement of oxygen by carbon dioxide. By

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the end of this phase, measurable concentrations of chemical oxygen demand (COD) and volatile organic acids (VOA) can be detected in the leachate.

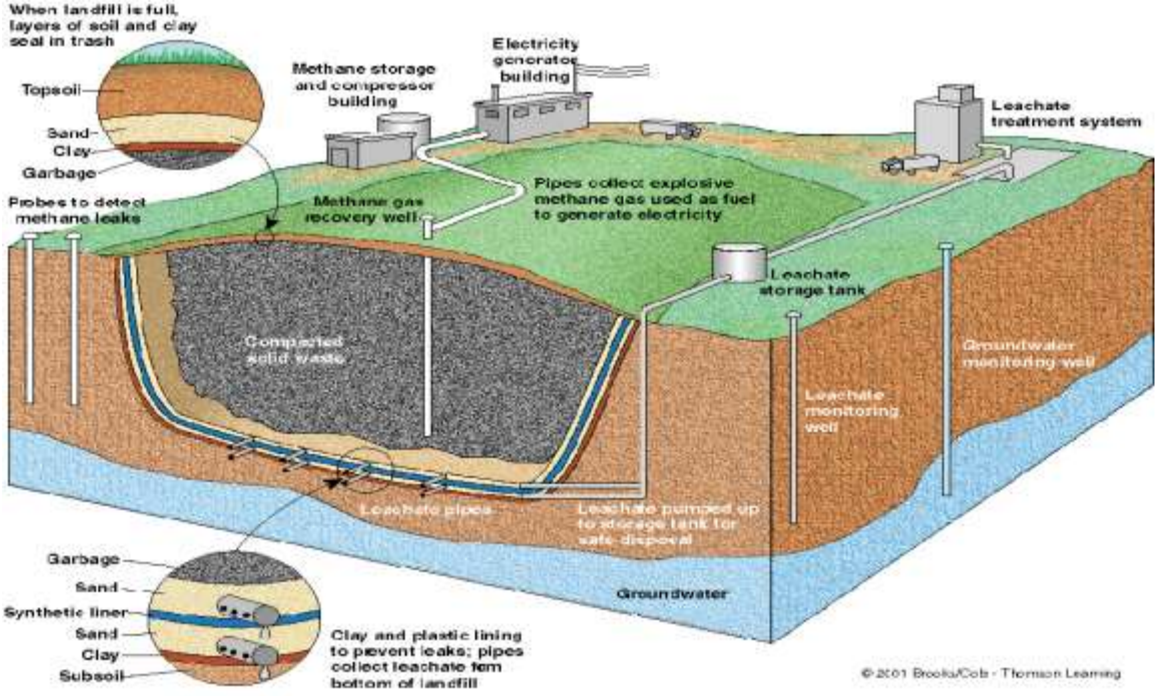
III: Acid formation **-** The continuous hydrolysis (solubilization) of solid waste, followed by (or concomitant with) the microbial conversion of biodegradable organic content results in the production of intermediate VOAs at high concentrations throughout this phase. A decrease in pH values is often observed, accompanied by metal species' mobilization. Viable biomass growth associated with the acid formers (acidogenic bacteria), and rapid consumption of substrate and nutrients are the predominant features of this phase.

IV: Methane fermentation **-** During Phase IV, intermediate acids are consumed by methane-forming consortia (methanogenic bacteria) and converted into methane and carbon dioxide. Sulphate and nitrate are reduced to sulphides and ammonia, respectively. The pH value is elevated, being controlled by the bicarbonate buffering system, and consequently supports the growth of methanogenic bacteria. Heavy metals are removed by complexation and precipitation.

V: Maturation **-** During the final state of landfill stabilization, nutrients and available substrate become limiting, and the biological activity shifts to relative dormancy. Gas production drops dramatically and leachate strength stays steady at much lower concentrations. Reappearance of oxygen and oxidized species may be observed slowly. However, the slow degradation of resistant organic fractions may continue with the production of humiclike substances.

Thus, the progress towards final stabilization of landfill solid waste is subject to the physical, chemical and biological factors within the landfill environment, the age and characteristics of landfilled waste, the operational and management controls applied, and the site-specific external conditions. Environmental conditions which most significantly impact upon biodegradation in landfills include pH, temperature, nutrients, absence of toxins, moisture content, particle size and oxidation-reduction potential etc,.

The schematic diagram below shows the sanitary land filling



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Landfills concept

Storage of any waste material in a landfill poses several potential problems. One problem is the possible contamination of soil, groundwater and surface water that may occur as leachate produced by water or liquid wastes moving into, through and out of the landfill migrates into adjacent areas. With the possibility of hazardous wastes, landfills should be designed to prevent any waste or leachate from ever moving into adjacent areas. **Leachate** is described as liquid that has percolated through the layers of waste material. Thus, leachate may be composed of liquids that originate from a number of sources, including precipitation, groundwater, consolidation, initial moisture storage, and reactions associated with decomposition of waste materials. The chemical quality of leachate varies as a function of a number of factors, including the quantity produced, the original nature of the buried waste materials and the various chemical and biochemical reactions that may occur as the waste materials decompose. In absence of evidence to the contrary, most regulatory agencies prefer to assume that any leachate produced will contaminate either ground or surface waters; in the light of the potential water quality impact of leachate contamination, this assumption appears reasonable.

Leachate Control

The quantity of leachate produced is affected to some extent by decomposition reactions and initial moisture content; however, it is largely governed by the amount of external and initial moisture content; however , it is largely governed by the amount of external water entering the landfill. Thus, a key first step in controlling leachate migration is to limit production by preventing, to the extent feasible, the entry of external water into the waste layers. A second step is to collect any leachate that is produced for subsequent treatment and disposal. Techniques are currently available to limit the amount of leachate that migrates into adjoining areas to a virtually immeasurable volume, as long as the integrity of the landfill structure and leachate control system is maintained. In Figure the bottom layer of soil may be naturally existing material or it may be hauled in, placed and compacted to specifications following excavation to a suitable sub grade. In either case, the base of the landfill should act as a liner with some minimum thickness and a very low hydraulic conductivity (or permeability). The barrier soil may be treated to reduce its permeability to an acceptable level. As an added factor of safety, an impermeable synthetic membrane is shown placed on the top of the barrier soil layer to form a composite liner. Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geomembrane. Above the primary liner are a geosynthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drain layers composed of sand layer that serve as drainage layers for leachate collection. The drain layers composed of sand are typically at least 1 ft thick and have suitably spaced collection pipe, avoiding a significant buildup of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effect is that very little leachate should percolate through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below should occur.

Drainage layers, geomembrane liners, and barrier soil liners may be referred to as the leachate collection and removal system or a double liner system. After the landfill is closed, the leachate collection and removal system serves basically in a back-up capacity. However, while the landfill is open and waste is being added, these components constitute the principal defense against contamination of adjacent areas. When the capacity of the landfill is reached, the waste cells may be covered with a cap or final cover, typically composed of four distinct layers. At the base of the cap there is a drainage layer and a liner system similar to that used at the base of landfill. The top of the barrier soil layer is graded so that water percolating into the drainage layer will tend to move horizontally towards some removal system located at the edge of the landfill. A layer of soil suitable for vegetative growth is placed at the top of the final cover system to complete the landfill. This upper layer is about 2-ft thick having loamy and silty soil, graded so that runoff is restricted and infiltration is controlled to provide moisture for vegetation while limiting percolation through the topsoil. Runoff is promoted but is controlled to prevent excessive erosion of the cap. Vegetation such as grasses best serve this purpose. The combination of site selection, surface grading, transpiration from vegetation, soil evaporation, drainage through the sand, and the low hydraulic conductivity of the barrier soil and geomembrane liners serves effectively to minimize leachate production from external water. The cap should be no more permeable than the leachate collection and removal system so that the landfill will not gradually fill and overflow into adjacent areas following abandonment of the landfill.

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Planning and design

The planning and designing of a bioreactor landfill requires

knowledge of the following:

- Landfill design and operation,
- Waste stream characteristics,
- Leachate quantity and quality,
- Leachate enhancement with nutrients, and
- Dynamics of waste degradation.
- Biogas collection and energy recovery

Legal issues, regulatory constraints, costs constraints, and public input may also influence planning and design. Because the system must function over the life of the landfill, SCS

designs are flexible enough to be adapted to regulatory changes, technological advances, economic conditions, and variation in waste and leachate characteristics.

Advantages

Engineered bioreactor landfills have the following advantages, if properly implemented and managed:

Enhance the Land filling gas generation rates: the generation and recovery of LFG under controlled conditions improves the quality of the LFG and this in turn improves the economics for LFG recovery and utilization.

Reduce environmental impacts: by containing the leachate and controlling the LFG emissions, engineered bioreactor landfills will have minimum impact on groundwater, surface water, and the neighboring environment. Another major benefit of bioreactor landfills is the reduction of greenhouse gas emissions to the environment.

Production of end product that does not need landfilling

by encouraging microbial degradation of solid waste and removal of inert end products through periodical engineered mining, the bioreactor land.ll cells could be re-used, and the end product could be spread on land as compost like material. The opportunity of reusing the bioreactor landfill cells highly improves the economics of the bioreactor cell technology.

Overall reduction of landfilling cost by successive re-uses of the same landfill cell, there are overall savings arising from not requiring the siting of new landfills every 15–20 years. Landfills could be built in modules, where additional cells can be added in the future as the need for additional capacity as the need arises. Reduction of leachate treatment capital and operating cost a landfill enhances the biological and chemical transformation of both organic and inorganic constituents within the landfill airspace, which will have an effect on the final leachate treatment requirements. Reduction in post-closure care, maintenance and risk a landfill minimizes long-term environmental risk and liability because of the controlled settlement of the solid waste during landfill operation, the low potential for leachate migration into the subsurface environment and the recovery of LFG during landfill operation. Proper maintenance of a landfill will reduce landfill monitoring activities and post closure care cost. Overall reduction of contaminating life span of the landfill this occurs as a result of a decrease in contaminant concentrations during the operating period of the landfills.

Monitoring parameters

A key component of the bioreactor process is to observe and measure what is taking place. This is particularly important during the developmental phase of the program but monitoring and testing will always be an integral part of bioreactor technology. The key monitoring parameters for bioreactor landfill operation is summarized below, Leachate **Flux**: Rates and locations of leachate and other fluids injection must be recorded to determine the relationship between influx and in situ moisture levels as well as leachate Removal rates.

Temperature: Waste mass temperature levels with time and their distribution provides a direct indication of biological activity. This is particularly important for aerobic treatment

where temperature must be controlled to avoid fires.

Moisture: Waste moisture content and distribution provides direct feedback on the effectiveness of the injection system and indicates how much liquid can still be received at a given location.

Cellulose and Lignin: These test results on recovered waste provide information on the level of biological activity and rate of progress. Leachate Yield and Quality - Leachate quantity recovered in a given area provide direct feedback on saturation levels in the waste and short circuits in the injection and recovery systems. Leachate quality results indicate the stage of the bioreactor process and will ultimately signal when biological activity is complete.

Waste Denstiy : The measured density of the waste mass and its distribution is a direct indicator of waste saturation and treatment level.

Settlement: Like density, settlement of the landfill surface and its development with time is a direct indicator of the progress of biological treatment. This data will ultimately

Indicate when biological treatment is complete and is very useful in computing remaining available airspace for planning and accounting purposes.

Gas Flow and Quality: Like leachate measurements, the gas data is an indicator of the level of biological activity and when tracked with time will show the rate of process development and when bioreactor treatment is complete. This information is also needed to plan expansion and modification of gas management systems.

Sustainable solid waste management in india

Trash and garbage disposal services, responsibility of local government workers in India, are ineffective. Solid waste is routinely seen along India's streets and shopping plazas. Trash and garbage is a common sight in urban and rural areas of India. It is a major source of pollution. Indian cities alone generate more than 100 million tons of solid waste a year. Street corners are piled with trash. Public places and sidewalks are despoiled with filth and litter, rivers and canals act as garbage dumps. In part, India's garbage crisis is from rising consumption. India's waste problem also points to a stunning failure of governance. In 2000, India's Supreme Court directed all Indian cities to implement a comprehensive waste-management program that would include household collection of segregated waste, recycling and composting. The Organization for Economic Cooperation and Development estimates that up to 40 percent of municipal waste in India remains simply uncollected. In 2011, several Indian cities embarked on waste to energy projects of the type in use in Germany, Switzerland and Japan. For example, New Delhi is implementing two incinerator projects aimed at turning the city's trash problem into electricity resource. These plants are being welcomed for addressing the city's chronic problems of excess untreated waste and a shortage of electric power. They are also being welcomed by those who seek to prevent water pollution, hygiene problems, and eliminate rotting trash that produces potent greenhouse gas methane. The projects are being opposed by waste collection workers and local unions who fear changing technology may deprive

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them of their livelihood and way of life. Delhi has set up Integrated Resource Recovery Facilities with an aggregate MSW capacity of 3,800 tons per day in six cities, along with the collection and transportation of MSW of an aggregate capacity of 910 TPD in two cities. They also have the processing and disposal of MSW of an aggregate capacity of 488 TPD in six cities in India.

Operational problems and research needs

Odor control can be more challenging when waste is wet. Consequently, the operator must be prepared to take appropriate action if problems arise. This could include quickly covering an area with earth or introducing a fresh waste layer over a land fill site. The operator also must be prepared to discontinue leachate recirculation if any of these issues emerges. To discontinue leachate recirculation, it may be necessary to have auxiliary leachate storage facilities, or to quickly move the leachate from the landfill to the treatment system. Plans for installing gas recovery equipment will need to be implemented on an ongoing basis during the operation. Landfill managers must primarily consider that they are dealing with a frequently changing landfill cell layout that is subject to settling. The shifting waste, as it rapidly decomposes, may break some of the collection equipment. So the operator needs to be prepared to quickly fix any damage that occurs to prevent odor problems and energy loss.

Conclusions

(1) Landfill is an essential part of an integrated waste management strategy, without which effective waste management will not be possible.
(2) The development of a truly sustainable landfill is important to the safe and effective management and control of waste in the future.
(3) As a solution to mismanaged open dumps in the country, a systematic rehabilitation strategy must be planned and executed. This planning should take into account the many benefits of operating dumpsites as and must be conceptualized accordingly while making proposals.
(4) Initiation of pilot scale and lab scale studies must be executed at the outset to experiment the feasibility of the technology for Indian refuse. Whether or not we are prepared to pay in the short term the price for truly sustainable landfill development remains to be seen. The long-term benefits are unquestioned.

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