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Management Model of Municipal Solid Waste Landfill Bioreactor

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ABSTRACT : ***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 is the most sought after managers proposition. 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. As compared to many developed countries, the concept of bioreactor landfills is still relatively very new to India. 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, bioreactor, leachate and biogas.***

Introduction

"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 minimises 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 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 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,.

BIOREACTOR LANDFILLS CONCEPTS

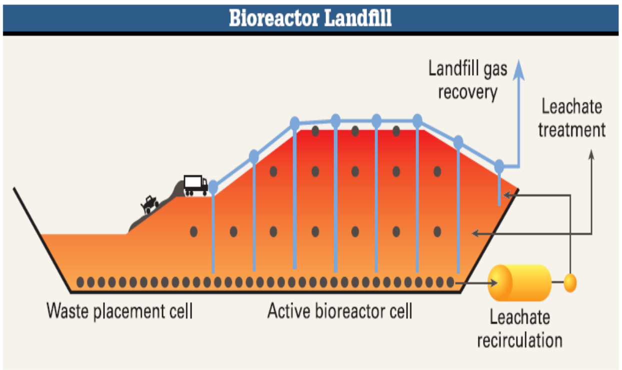
The underlying principle of the bioreactor landfill is that by optimizing operational control and environmental conditions within the waste (especially moisture content), more rapid and complete degradation of waste may be achieved. The general objective is to produce a "stable waste" within a reasonable time scale, and thus ensure that the risk to the environment will be at an acceptable level when liner failure occurs. The schematic view of bioreactor landfills is provided in Figure.

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 - Phydical process involves, shredding of the waste to an 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.



Source: Patrick Walsh and Philip O' Leary (2002)(10)

Figure - Schematic view of bioreactor landfill

BIOREACTOR LANDFILL TYPES

There are three different general types of bioreactor landfill configurations:

Aerobic - Leachate is removed from the bottom layer, piped to liquids storage tanks, and recirculated into the landfill in a controlled manner. Air is injected into the waste mass, using vertical or horizontal wells, to promote aerobic activity and accelerate waste stabilization.

Anaerobic - Moisture is added to the waste mass in the form of recirculated leachate and other sources to obtain optimal moisture levels. Biodegradation occurs in the absence of oxygen (anaerobically) and produces landfill gas. Landfill gas, primarily methane, can be captured to minimize greenhouse gas emissions and for energy projects.

Hybrid (Aerobic-Anaerobic) - The hybrid bioreactor landfill accelerates waste degradation by employing a sequential aerobic-anaerobic treatment to rapidly degrade organics in the upper sections of the landfill and collect gas from lower sections. Operation as a hybrid results in an earlier onset of methanogenesis compared to aerobic landfills.

ADVANTAGES OF BIOREACTOR LANDFILLS

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

Enhance the LFG 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 re-using 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 bioreactor landfill cell, there are overall savings arising from not requiring the siting of new landfills every 15–

20 years. Bioreactor 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 bioreactor 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 bioreactor 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 operation of a bioreactor 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 bioreactor landfills.

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.

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 from the LCRS 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.

APPROACH FOR SUSTAINABLE SOLID WASTE MANAGEMENT IN INDIA

As compared to many developed countries, the concept of bioreactor landfill operation is still relatively very new to India. As a solution to mismanaged open dumps in the country, a systematic rehabilitation strategy must be planned and executed. The simplest thing that can be achieved in the short term without much additional investments to significantly improve the open dumps and reduce its adverse impacts and associated nuisances is to move to controlled tipping. This can be followed up with gradual and obvious adoption of engineering techniques. Movement from the controlled dumping to engineered landfills may be a long term goal depending on the availability of physical and financial resources. The waste degradation in landfills can be accelerated by operating it in the bioreactor mode and in the end; the “stabilized” waste mass with limited methane and odor production and less harmful leachate that can be recovered creates valuable landfill airspace.In addition, the waste is in a safer condition to mine and recycle, paving the way to “reusable” or “sustainable” landfills and lowering life-cycle landfill costs

OPERATION 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 bioreactor cell. 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 bioreactor's 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.

CONCLUSION

Landfill is an essential part of an integrated waste management strategy, without which effective waste management will not be possible. The development of a truly sustainable landfill will be important to the safe and effective management and control of waste in the future. As compared to many developed countries, the concept of bioreactor landfills is still relatively very new to India. 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 bioreactors and must be conceptualized accordingly while making proposals. Initiation of pilot scale and lab scale bioreactor 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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