Bioreactor Landfills: A Viable Technology

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BACKGROUND

According to recent studies, the United States generates some 545 million tons of non-hazardous waste per year, of which almost 70 percent is disposed of in landfills. Regulations promulgated under Subtitle D of the Resource Conservation and Recovery Act (RCRA) require municipal solid waste (MSW) landfills to be protective of human health and the environment. In order to meet the RCRA requirements, landfills are designed with impermeable liners and leachate collection systems to prevent groundwater contamination, a low permeability cap to prevent liquid intrusion after closure, and a landfill gas extraction system to prevent air emissions. In addition, owners are required to maintain the landfill for 30 years or more after final closure and provide financial assurance for these activities.

One of the major concerns addressed by the RCRA requirements was to minimize the potential for groundwater contamination. This approach resulted in MSW landfills becoming "dry tombs" (i.e., lacking water). However because of moisture limitations, the biodegradation of the organic material by bacteria in an MSW landfill proceeds at a very slow rate.

Despite being able to provide environmental protection, the "dry tomb" landfill has many drawbacks including:

- The production of leachate and air emissions for an extended time period that must be monitored, controlled, and treated;
- An extended post-closure care period because of waste settlement (i.e., the final cap settles as waste decomposes); and
- A decreased landfill life because landfills are typically permitted to accept a set volume of waste.

LANDFILL ALTERNATIVE

As an alternative to "dry tomb" landfills, bioreactor landfills are designed to promote the rapid decomposition of the organic portion of the MSW. This is accomplished by maintaining optimal moisture conditions at or near field capacity (approximately 34 to 65 percent). At a minimum, leachate is injected into the landfill to stimulate naturally occurring microorganisms that can be either aerobic (with oxygen) or anaerobic (without oxygen). However, bioreactor landfills often need other liquids such as stormwater, wastewater, and wastewater treatment plant sludges to supplement leachate for maintenance of optimal moisture levels. Liquids are added to the landfill through vertical wells, horizontal pipes, or trenches. The primary purpose of a bioreactor landfill is to accelerate decomposition of the organic fraction of the MSW to less than ten years (i.e., rather than 30 or more years).

BIOREACTOR BENEFITS

Because decomposition and biological stabilization of the waste in a bioreactor landfill occurs in a much shorter time period than in a "dry tomb" landfill (i.e., years versus decades), the potential advantages of the bioreactor landfill can include:

- Reduced leachate disposal costs;
- Increased waste decomposition and settlement that results

Types of Bioreactor Landfill Configurations

Type	Description	Configuration
Aerobic	In an aerobic bioreactor, biodegradation occurs in the presence of air, which contains oxygen.	Air is injected into the waste mass using vertical or horizontal wells to promote aerobic bacteria to accelerate waste decomposition. The degradation of waste occurs under conditions similar to compost operations. The byproducts of aerobic degradation are carbon dioxide (CO_2) and water (H_2O).
Anaerobic	In an anaerobic bioreactor, biodegradation occurs in the absence of air and oxygen.	Without air, methanogenetic bacteria are promoted to accelerate waste degradation. The byproducts of anaerobic degradation are methane (CH_4) that can be used as an alternative energy source and CO_2.
Hybrid (Aerobic-Anaerobic)	In a hybrid bioreactor landfill the waste is first degraded under aerobic conditions followed by anaerobic conditions.	Aerobic conditions usually occur in the newly placed waste in the upper sections of the landfill, while anaerobic conditions occur in the lower sections. Because anaerobic conditions exist in the older lower sections of the landfill, methane production still occurs.

in additional air space. This space can be as much as 40 percent;

- Reduced post-closure care periods and costs;
- Increased revenues through acceptance of liquid wastes;
- Shortened time periods over which air and water emissions are generated and must be controlled resulting in increased environmental protection;
- Increased methane production over shorter time periods making methane recovery and use as an energy source more economical; and
- Faster return of the landfill to a productive end-use.

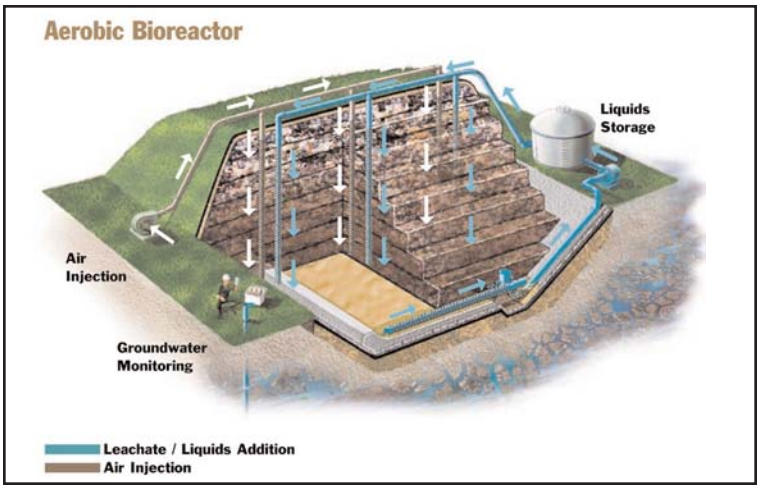
Despite the potential advantages of bioreactor landfills, the current federal regulations do not allow bioreactor landfills because liquids cannot be accepted at landfills and leachate can only be recirculated within a landfill cell that has a composite liner (i.e., 30-mil flexible membrane liner underlain by two feet of soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec). However, EPA is considering amending the Subtitle D rules for MSW landfills to accommodate bioreactor landfills.

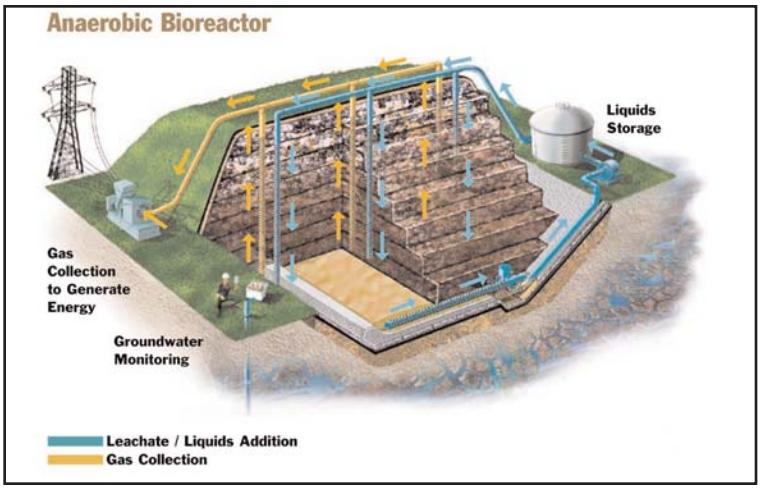
DEVELOPING REGULATIONS

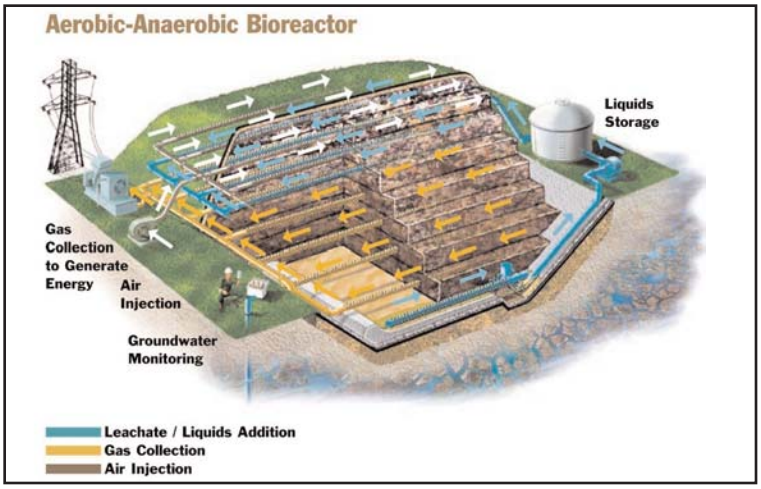
According to EPA, several considerations about bioreactor landfills must be examined and understood before it can identify specific bioreactor standards or recommended operating parameters. EPA believes that bioreactor landfills may require additional monitoring and control during their operational life because of their highly engineered systems (e.g., liquid delivery systems, leachate collections systems, and gas collection systems) and the addition of excess liquids. The agency needs to address the following issues before making any decision: an increase in gas emissions, an increase in odors, the physical instability of waste mass because of increased moisture and density, surface seeps, and landfill fires.

EPA estimates that the number of bioreactor landfill projects underway is about 150. These projects are studying and/or conducting research and demonstrations on bioreactor landfills and landfills that recirculated leachate. The type of data that is being collected includes:

- The performance of alternative liner designs and materials for leachate recirculation and bioreactor landfills;







- The physical stability of covers and bottom liners during and after operation;
- The impacts of leachate and added liquid quality, quantity, and loading on the liner system;
- The time and amount of liquid required to reach field capacity;
- An appropriate way to measure field capacity in the waste;
- Liquid additions and its affect on the rate and extent of landfill stabilization;

- An appropriate way to measure stabilization;
- Specifications for the design, operation, and performance of bioreactor landfills;
- Gas generation rate, quantity, and quality;
- Appropriate interim and final covers after waste placement to accommodate anticipated waste settlement;
- Daily and final cover performance;
- Methods for optimum moisture content and distribution;
- Monitoring requirements; and
- Impacts on capping, and current closure and post-closure care requirements.

DATA COLLECTION

Currently, EPA is conducting a State-of-the-Practice Bioreactor Landfill Study to compare data from bioreactor landfills with those from traditional dry tomb landfills. The study will examine five operating bioreactor landfills and identify the regulatory, environmental, and operating parameters of these landfills. Once this data and data from other research and demonstration projects are collected, EPA plans to develop a technical guidance and/or best practices for design, operation, and permitting of bioreactor landfills.

The following is a list of research, development and demonstration (RD&D) projects on bioreactor landfills where additional information is being collected:

▷ EPA's Project XL – The Project XL (eXcellance and Leadership) program is an EPA initiative that provides regulatory flexibility to entities to conduct pilot projects that demonstrate the ability to achieve superior environmental performance (http://www.epa.gov/projectxl). Currently, four landfill pilot projects have been approved to operate as bioreactors. These include:

-- Buncombe County Landfill Project, North Carolina (http://www.epa.gov/projectxl/buncombe/index.htm),

-- Maplewood Landfill and King George County Landfills, Virginia (http://www.epa.gov/projectxl/virginialandfills.htm), and

-- Yolo County Bioreactor Landfill, California (http://www.epa.gov/projectxl/yolo/index.htm).

▷ Environmental Research and Education Foundation (EREF) – The EREF is presently working with Michigan State University and Northern Oaks Landfill to develop a bioreactor landfill cell and monitor the water and gas emissions over a long term. The EREF has also funded the development of a bioreactor landfill bibliography and a project to determine the fate of nitrogen at a bioreactor landfill in Florida (http://www.erefdn.org).

▷ Florida Center for Solid and Hazardous Waste Management (FCSHWM) – The FCSHWM, in conjunction with the University of Central Florida and University of Florida, is under taking a project that will develop and demonstrate a scaled-up, fully instrumented landfill cell, engineered from the start as a bioreactor facility. The project will be constructed at the New River Solid Waste Authority landfill in Florida (http://bioreactor.org).

▷ Environmental Control Systems, Inc. (ECS) – ECS has been working on a method for treating biodegradable waste material in a landfill under aerobic conditions. The company has several projects underway in Georgia and Tennessee using the aerobic bioreactor landfill process (http://www.aerobiclandfill.com/landfill.htm).

▷ Yolo County – The Yolo County Landfill is constructing and monitoring a large-scale bioreactor in California to better understand the pros and cons of bioreactors (http://www.yolocounty.org/org/PPW/diwm/bioreactor.htm).

Additional information on bioreactor landfills is available through a number of conference proceedings. EPA holds a bioreactor workshop semiannually and posts the proceedings on the Internet at www.epa.gov/garbage/landfill/bio-work/index.htm. The National Solid Wastes Management Association's Waste Tech Conference that is held annually at the Waste Expo show is another source for bioreactor research papers.

CONCLUSION

Bioreactor landfills have the potential to be a viable option for the management of municipal solid waste. However, answers to some basic questions about the bioreactor technology need to be addressed before the federal regulations are amended to allow widespread use of bioreactors.

**Thank you to Waste Management, Inc. (Houston, Texas) for the drawings of bioreactor landfills on page 2.*