U.S. Environmental Protection Agency

Municipal Solid Waste

Bioreactors

What is a Bioreactor Landfill?

A bioreactor landfill operates to rapidly transform and degrade organic waste. The increase in waste degradation and stabilization is accomplished through the addition of liquid and air to enhance microbial processes. This bioreactor concept differs from the traditional "dry tomb" municipal landfill approach.

A bioreactor landfill is not just a single design and will correspond to the operational process invoked. There are three different general types of bioreactor landfill configurations:

- **Aerobic** - In an aerobic bioreactor landfill, leachate is removed from the bottom layer, piped to liquids storage tanks, and re-circulated 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** - In an anaerobic bioreactor landfill, moisture is added to the waste mass in the form of re-circulated 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 the earlier onset of methanogenesis compared to aerobic landfills

The Solid Waste Association of North America (SWANA) has defined a bioreactor landfill as "any permitted Subtitle D landfill or landfill cell where liquid or air is injected in a controlled fashion into the waste mass in order to accelerate or enhance biostabilization of the waste." The United States Environmental Protection Agency (EPA) is currently collecting information on the advantages and

Key Topics

Meetings

Bioreactor Workshop, February 27-28, 2003 [PDF File, 226 KB]

Agenda for Bioreactor Workshop - Feb. 2003 [PDF File, 135 KB] disadvantages of bioreactor landfills through case studies of existing landfills and additional data so that EPA can identify specific bioreactor standards or recommend operating parameters. The information on this web page is organized to give you information about:

- Features Unique to Bioreactor Landfills
- Potential Advantages of Bioreactor Landfills
- Special Considerations of Bioreactor
- Landfills
- Current EPA Bioreactor Research

Features Unique to Bioreactor Landfills

The bioreactor accelerates the decomposition and stabilization of waste. At a minimum, leachate is injected into the bioreactor to stimulate the natural biodegradation process. Bioreactors often need other liquids such as stormwater, wastewater, and wastewater treatment plant sludges to supplement leachate to enhance the microbiological process by purposeful control of the moisture content and differs from a landfill that simple recirculates leachate for liquids management. Landfills that simply recirculate leachate may not necessarily operate as optimized bioreactors.

Moisture content is the single most important factor that promotes the accelerated decomposition. The bioreactor technology relies on maintaining optimal moisture content near field capacity (approximately 35 to 65%) and adds liquids when it is necessary to maintain that percentage. The moisture content, combined with the biological action of naturally occurring microbes decomposes the waste. The microbes can be either aerobic or anaerobic. A side effect of the bioreactor is that it produces landfill gas (LFG) such as methane in an anaerobic unit at an earlier stage in the landfill's life and at an overall much higher rate of generation than traditional landfills.

Potential Advantages of Bioreactor Landfills

Decomposition and biological stabilization of the waste in a bioreactor landfill can occur in a much shorter time frame than occurs in a traditional "dry tomb" landfill providing a potential decrease in long-term environmental risks and landfill operating and post-closure costs. Potential advantages of bioreactors include:

- Decomposition and biological stabilization in years vs. decades in "dry tombs"
- Lower waste toxicity and mobility due to both aerobic and anaerobic conditions
- Reduced leachate disposal costs
- A 15 to 30 percent gain in landfill space due to an increase in density of waste mass
- Significant increased LFG generation that, when captured, can be used for energy use onsite or sold
- Reduced post-closure care

Research has shown that municipal solid waste can be rapidly degraded and made less hazardous (due to degradation of organics and the sequestration of inorganics) by enhancing and controlling the moisture within the landfill under aerobic and/or anaerobic conditions. Leachate quality in a bioreactor rapidly improves which leads to reduced leachate disposal costs. Landfill volume may also decrease with the recovered airspace offering landfill operators the extend the operating life of the landfill.

LFG emitted by a bioreactor landfill consists primarily of methane and carbon dioxide plus lesser amounts of volatile organic chemicals and/or hazardous air pollutants. Research indicates that the operation of a bioreactor may generate LFG earlier in the process and at a higher rate than the traditional landfill. The bioreactor LFG is also generated over a shorter period of time because the LFG emissions decline as the accelerated decomposition process depletes the source waste faster than in a traditional landfill. The net result appears to be that the bioreactor produces more LFG overall than the traditional landfill does.

Some studies indicate that the bioreactor increases the feasibility for cost effective LFG recovery, which in turn would reduce fugitive emissions. This presents an opportunity for beneficial reuse of bioreactor LFG in energy recovery projects. Currently, the use of LFG (in traditional and bioreactor landfills) for energy applications is only about 10 percent of its potential use. The US Department of Energy estimates that if the controlled bioreactor technology were applied to 50 percent of the waste currently being landfilled, it could provide over 270 billion cubic feet of methane a year, which is equivalent to one percent of US electrical needs.

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Special Considerations of Bioreactor Landfills

Several considerations about bioreactor landfills must be examined and understood before the EPA can identify specific bioreactor standards or recommend operating parameters. Bioreactor landfills generally are engineered systems that have higher initial capital costs and require additional monitoring and control during their operating life, but are expected to involve less monitoring over the duration of the post-closure period than conventional "dry tomb" landfills. Issues that need to be addressed during both design and operation of a bioreactor landfill include:

- Increased gas emissions
- Increased odors
- Physical instability of waste mass due to increased moisture and density
- Instability of liner systems
- Surface seeps
- Landfill fires

Current EPA Bioreactor Research

EPA and its state and industry partners are studying and conducting research and demonstrations on bioreactor landfills and other landfills, such as those that re-circulate leachate. EPA hopes to learn more about the possible effects of bioreactor operations and the costs that may be associated with them. EPA's Offices of Solid Waste; Air and Radiation; Policy, Economics, and Innovation; and Research and Development are examining various aspects of bioreactor landfills in order to:

- Assess the state-of-the-practice of bioreactor landfill design, operation, and maintenance
- Identify case studies of bioreactor landfill use, especially where data exist for comparison between traditional and bioreactor approaches
- Determine long-term monitoring needs for environmental compliance for groundwater, gas emissions, leachate quality, liner stability, physical stability, and other factors to satisfy life-cycle integrity and economic viability concerns
- Exchange views, technical concerns, and implementation concerns regarding (1) pending and planned regulations effecting landfills in general

and (2) the regulatory framework to be developed for bioreactor landfills
- Examine the economic viability, impacts, and benefits of bioreactor landfill implementation at full scale
- Identify and prioritize research and regulatory needs

In order for EPA to make a determination regarding the benefits of bioreactors, as well as to understand the concerns associated with them, EPA will need to collect data on:

- Alternative liner design/materials for leachate re-circulation and bioreactor landfills
- Physical stability of the cover and bottom liner during and after operation
- Impacts of leachate quality, quantity, and loading on the liner system
- Times and amounts of liquids it takes to reach field capacity
- Appropriate means for measuring field capacity
- Leachate re-circulation and its affect on the rate and extent of landfill stabilization
- Stabilization measures
- Design, operation, and performance specifications for bioreactors
- Rate, quantity, and quality of gas generation
- Interim covers used after placement to accommodate anticipated settlement
- Daily and final cover performance
- Optimum moisture content and distribution methods
- Monitoring requirements
- Bioreactor technology impacts on capping, and current closure and post-closure requirements

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Bioreactor Projects within EPA

The following is a list of the bioreactor research studies, demonstrations, and guidance projects currently underway within EPA.

1. Project XL Bioreactor Landfill Pilots

Project XL (eXcellence and Leadership) is an EPA initiative begun in 1995. The program provides limited regulatory flexibility for regulated entities to conduct pilot projects that demonstrate the ability to achieve superior environmental performance. The information and lessons learned from Project XL are being used to assist EPA in redesigning its current regulatory and policy-setting approaches. As of September 2001, 51 pilot experiments are being implemented. Of those being implemented in this innovative program, four landfill pilot projects have been approved to operate as bioreactors. These landfill pilot projects 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/index.htm)
- Yolo County Bioreactor Landfill, California (http://www.epa.gov/projectxl/yolo/index.htm)

EPA will provide these facilities with regulatory flexibility that will allow them to re-circulate leachate and other liquids over a municipal solid waste landfill unit constructed with an alternative liner system. In turn, the designers of these bioreactor XL projects hope that, when implemented, the leachate re-circulation/gas recovery landfill approach will provide superior environmental performance in a number of ways. These improvements include the following:

- Enhanced groundwater protection
- Reduced landfill gas emissions by early installation of, and operation of, gas collection and control systems
- Additional waste capacity and longer life of existing landfill cells, thereby reducing the need for new landfill sites, and
- Improved leachate quality and - ultimately - cleaner wastewater discharges.

EPA expects to obtain significant information on bioreactor technology from these projects.

All of the Project XL bioreactor pilot projects will be evaluated on superior environmental performance, cost savings, paperwork reduction, sustainablility, innovation, feasibility, and identification of monitoring and reporting methods. The results of the bioreactor XL projects may provide information to EPA on modifying specific criteria in the 258 regulation. (More information on these projects can be found at this web address: http://www.epa.gov/projectxl.

Time Frame: The pilot demonstrations are expected to be completed according to the agreed-upon duration for each individual project, between 2006 and 2026. The evaluations will be ongoing, and will be completed shortly after each pilot is completed.

2. EPA State-of-the-Practice Bioreactor Landfill Study

EPA is conducting a State-of-the-Practice Bioreactor Landfill Study. The purpose of this study is to compare data from bioreactor landfills with that from traditional dry landfills. This study will survey five operating bioreactor landfills and identify the regulatory, environmental, and operating parameters of these landfills, and will begin identifying and evaluating best operating practices. The study will assist EPA in determining long-term monitoring needs for environmental compliance with groundwater standards, gas emissions, leachate quality, liner stability, physical stability, and other factors to address life-cycle integrity and economic viability concerns. The information will assist owners and/or operators, as well as permit writers, to better operate and/or regulate bioreactor landfills. In addition, this study should lay the groundwork for EPA to develop technical guidance and/or best practices for design, operation and permitting the bioreactor landfill.

Time Frame: A final report is expected to be completed in late 2002

3. Cooperative Research with Waste Management using a CRADA (Cooperative Research and Development Agreement)

EPA's National Risk Management Research Laboratory is partnering with Waste Management, Inc. to conduct research on several large-scale bioreactor landfills looking at several variables. This work is being conducted through a Cooperative Research and Development Agreement (CRADA). The purpose of this five-year, joint research effort is to collect sufficient information in order to ascertain the best operating practices to promote safe operation of bioreactor landfills.

Various design and operating features are being studied, including (1) Aerobic, and (2) Anaerobic

Time Frame: The CRADA will be in effect from 2001-2006. Results of this project will be used to assist in the development of bioreactor guidance documents and standard operating procedures.

Additional Bioreactor Projects and Information

External Links

For more information on bioreactors and bioreactor projects, click on the following links:

- www.bioreactor.org EXIT EPA provides information about the Bioreactor Landfill Demonstration Project. Originally begun in 1998, the Bioreactor Landfill Demonstration Project is a five-year project managed by the Florida Center for Solid and Hazardous Waste Management.
- www.aerobiclandfill.com/landfill.htm EXIT EPA provides information on aerobic landfill technology provided by Environmental Control Systems, Inc.
- http://www.wm.com/bio.asp EXIT EPA provides information on bioreactor technology provided by Waste Management, Inc.
- http://www.yolocounty.org/org/PPW/diwm/bioreactor.htm EXIT EPA provides information on the Yolo County Central Landfill which is demonstrating an innovative landfill management strategy called "enhanced or controlled" landfilling to manage solid waste.

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URL: http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/bioreactors.htm