INTRODUCING

THE BIOREACTOR LANDFILL

NEXT GENERATION LANDFILL TECHNOLOGY

WASTE MANAGEMENT

Bioreactor Program

The Bioreactor Landfill: The Future of Landfill Management

Small Changes in Landfill Operation Today will Yield Large Environmental Benefits Tomorrow

WASTE MANAGEMENT has prepared this brochure to share our vision of the future of landfill management and to describe the steps that we are taking to realize this vision.

Looking to the future, we see that as a society we will need to continuously improve the way that we manage our wastes. Source reduction and recycling efforts will take on increasingly important roles, but landfill disposal will remain an essential component of integrated waste management strategies for the foreseeable future.

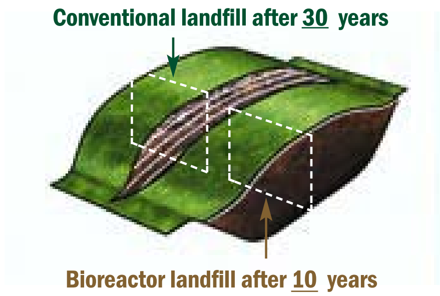
We believe there are significant environmental and economic benefits to be gained by making small changes in the way that we operate landfills. We see the potential to revolutionize landfills from secure waste repositories to waste treatment systems, to significantly reduce or even eliminate long-term risk to the environment while simultaneously extracting further value. We are optimistic that these things can be accomplished. Here is why.

LEADING-EDGE INNOVATION AND TECHNOLOGY ACCELERATES WASTE DECOMPOSITION

The engineered landfill is an environmentally sound system for solid waste disposal. At Waste Management, we are proud that we were at the forefront in developing and implementing many of the practices, such as leachate and gas collection and management, that now constitute the standards for environmentally responsible landfill design and operation.

From a pollution prevention standpoint, the control features oft he modern landfill have been an unqualified success. But we have also learned that these same control features retard the natural decomposition processes in the landfill by making it a dry tomb. Under these conditions waste decomposes over a period of decades, slowly producing gas and settling until the waste is biologically stable.

Now imagine that the natural decomposition of waste in the landfill



could be accelerated to occur within years instead of decades, and that this could be achieved while enhancing environmental protection. This is the concept behind bioreactor landfill technology and it is the basis for our optimism.

BIOREACTOR LANDFILL TECHNOLOGY

Bioreactor technology accelerates the biological decomposition of food, greenwaste, paper and other organic wastes in a landfill by promoting conditions necessary for the microorganisms that degrade the waste. The single most important factor in promoting waste decomposition is the moisture content of the waste.

Liquids must be added to the waste mass to obtain optimal moisture content, which ranges from 35 to 45 percent water by weight. Liquids that are added include: landfill leachate, gas condensate, water, storm water runoff, and wastewater treatment sludges.

BIOREACTOR LANDFILL BENEFITS

- Accelerated waste stabilization. Stabilized landfills can be converted to other useful purposes years sooner with greater assurance of environmental safety.
- Recovery of 15 to 35 percent of landfill space as waste decomposes and is converted to gas extends the useful life of landfills, reducing the need to site new facilities.
- Expanded and concentrated production of methane gas favors beneficial gas use projects while decreasing greenhouse gas emissions over the life of the landfill.
- Leachate recirculation reduces leachate management costs while improving leachate quality.
- Provide an environmentally sound alternative to the land application of certain liquid wastes.

WASTE MANAGEMENT'S BIOREACTOR LANDFILL RESEARCH AND DEVELOPMENT EFFORTS INCLUDE:

- Building on our own experience with bioreactors and leachate recirculation projects, we have begun an ambitious program to evaluate multiple full-scale bioreactor projects.
- Establishing relationships with leading researchers from academia and industry to further the understanding of bioreactor processes and the development of new tools for investigating landfill processes.
- Cooperatively working with federal and state regulatory agencies.
- Economics of full-scale bioreactor operations.

AREAS OF FOCUS:

- Bioreactor process types and operational implementation
- Impacts of geography and climate on bioreactor performance
- Nitrogen management in landfills
- Alternative sources of moisture
- Landfill gas production and emissions
- Landfill stability (geotechnical)
- Regulatory change

BIOREACTOR LANDFILL PROCESSES

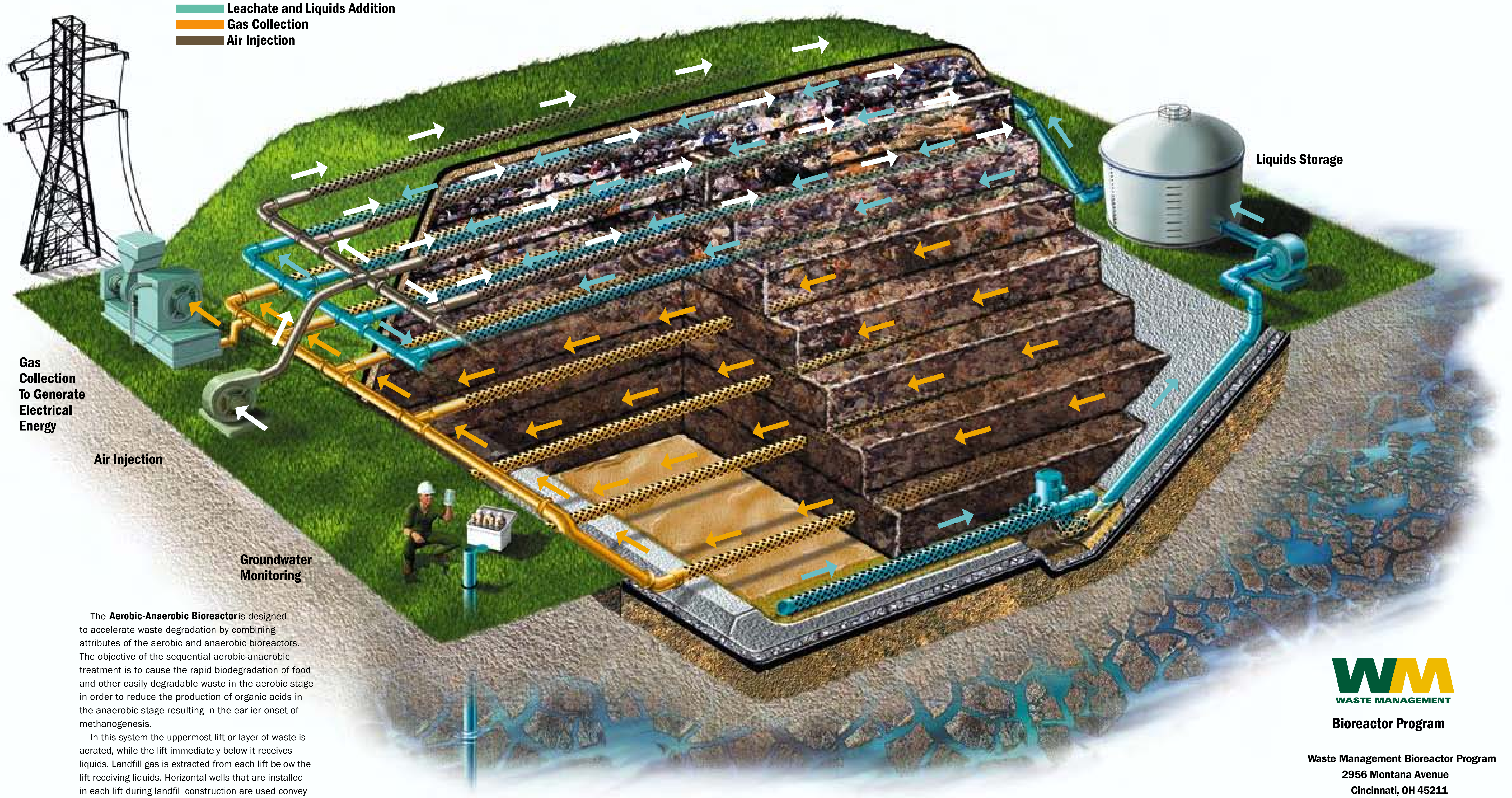
Waste Management is evaluating four types of bioreactor technology:

- Aerobic-Anaerobic
- Anaerobic
- Aerobic
- Facultative

Waste Management is evaluating these bioreactor types at existing landfills (retrofit) and at those that are being constructed (as built). The following pages describe such technologies and applications.

Aerobic-Anaerobic Bioreactor

(US Patent 6,283,676 B1)



The **Aerobic-Anaerobic Bioreactor** is designed to accelerate waste degradation by combining attributes of the aerobic and anaerobic bioreactors. The objective of the sequential aerobic-anaerobic treatment is to cause the rapid biodegradation of food and other easily degradable waste in the aerobic stage in order to reduce the production of organic acids in the anaerobic stage resulting in the earlier onset of methanogenesis.

In this system the uppermost lift or layer of waste is aerated, while the lift immediately below it receives liquids. Landfill gas is extracted from each lift below the lift receiving liquids. Horizontal wells that are installed in each lift during landfill construction are used convey the air, liquids, and landfill gas.

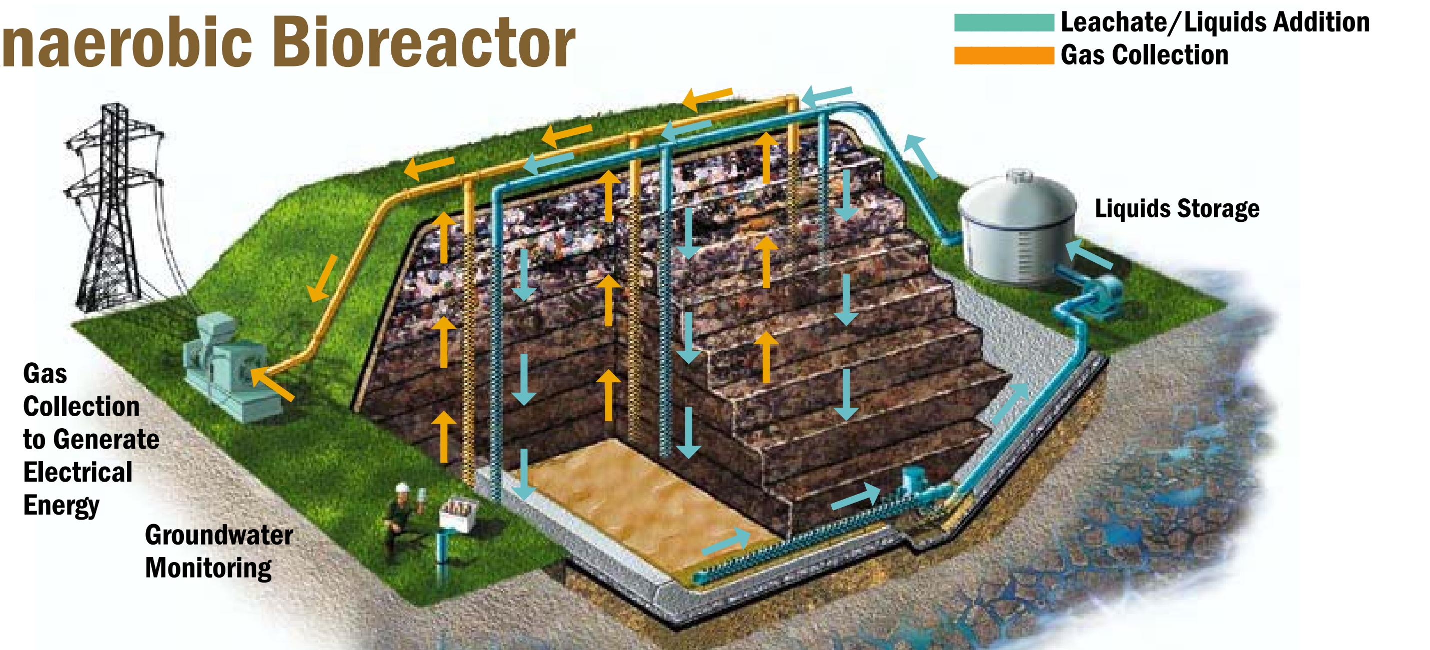
The principle advantage of the hybrid approach is that it combines the operational simplicity of the anaerobic process with the treatment efficiency of the aerobic process. Added benefits include an expanded potential for destruction of volatile organic compounds in the waste mass.

WASTE MANAGEMENT

Bioreactor Program

Waste Management Bioreactor Program
2956 Montana Avenue
Cincinnati, OH 45211
Phone 513-389-7370
Fax 513-389-7374

Anaerobic Bioreactor



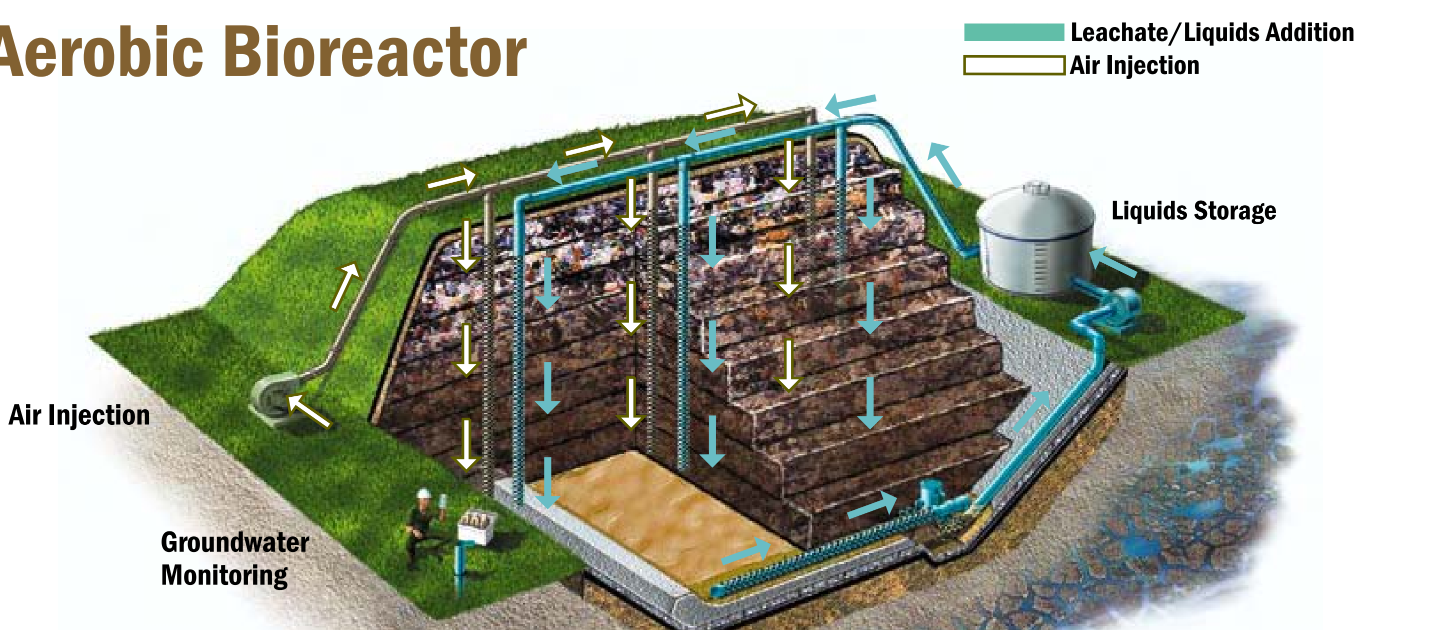
The **Anaerobic Bioreactor** seeks to accelerate the degradation of waste by optimizing conditions for anaerobic bacteria. In landfills, consortia of anaerobic bacteria are responsible for the conversion of organic wastes into organic acids and ultimately into methane and carbon dioxide.

Anaerobic conditions develop naturally in nearly all landfills without any intervention. The waste in typical landfills contains between 10 and 25 percent water. It is generally accepted that to optimize anaerobic degradation moisture conditions at or near field capacity, or about 35 to 45 percent moisture, are required.

Moisture is typically added in the form of leachate through a variety of delivery systems. However, the amount of leachate produced at many sites is insufficient to achieve optimal moisture conditions in the waste. Additional sources of moisture such as sewage sludge, storm water, and other non-hazardous liquid wastes may therefore be necessary to augment the leachate available for recirculation.

As the moisture content of the waste approaches optimal levels, the rate of waste degradation increases, this in turn leads to an increase in the amount of landfill gas produced. Also observed is an increase in the density of the waste. While the rate of gas production in an anaerobic bioreactor can be twice as high as a normal landfill, the duration of gas production is significantly shorter. Because of this accelerated production, gas collection systems at bioreactor landfills must be capable of handling a higher peak volume but need do so for a shorter period of time.

Aerobic Bioreactor



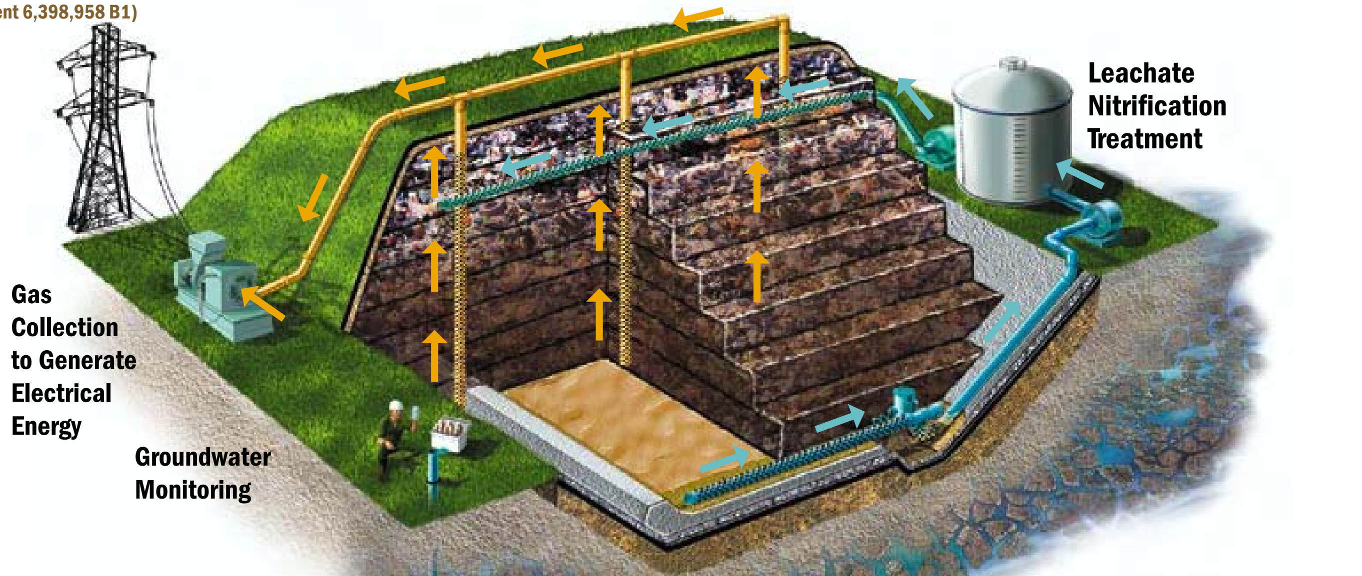
The **Aerobic Bioreactor** seeks to accelerate waste degradation by optimizing conditions for aerobes. Aerobes are organisms that require oxygen for cellular respiration. In aerobic respiration, energy is derived from organic molecules in a process that consumes oxygen and produces carbon dioxide.

Aerobes require sufficient water to function just as anaerobes do. However, aerobic organisms can grow more quickly than anaerobes because aerobic respiration is more efficient at generating energy than anaerobic respiration. One consequence of this is that aerobic degradation can proceed faster than anaerobic degradation. Another consequence is that aerobic respiration can generate large amounts of metabolic heat, which requires significant quantities of water.

In landfills aerobic activity is promoted through injection of air or oxygen into the waste mass. It is also possible to apply a vacuum to the waste mass and pull air in through a permeable cap. Liquids are typically added through leachate recirculation, with the need for additional sources of moisture even more acute than for anaerobic reactors. The aerobic process does not generate methane.

Facultative Bioreactor

(US Patent 6,398,958 B1)



The **Facultative Bioreactor** combines conventional anaerobic degradation with a mechanism for controlling the high ammonia concentrations that may develop when liquids are added to the landfill. In this system leachate containing elevated levels of ammonia is treated using the biological process of nitrification. The nitrification process converts the ammonia in the leachate to nitrate. The treated leachate is then added to the landfill. Here certain microorganisms including the facultative bacteria can use the nitrate in the absence of oxygen for respiration. This process, called denitrification, can result in the production of nitrogen gas (N_2), which effectively removes nitrogen from the system.

As with other forms of bioreactor landfills, the facultative bioreactor requires adequate moisture levels to function optimally. Leachate and other liquids (e.g., biosolids, liquid wastes, surface water, etc.) are used to raise the moisture content of the waste.

WASTE MANAGEMENT ENVIRONMENTAL POLICY

Waste Management is committed to protecting human health and the environment. This commitment is a keystone of all that we do, reflected in the services we provide to customers, the design and operation of our facilities, the conditions under which employees work, and our interactions with the communities where we live and do business. We will be responsible stewards of the environment and protect the health and well-being of our employees and neighbors.

WM WASTE MANAGEMENT

Bioreactor Program

Waste Management Bioreactor Program
2956 Montana Avenue • Cincinnati, OH 45211
Phone 513-389-7370 • Fax 513-389-7374