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Extension FactSheet

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Bioreactor Landfills

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Introduction

The production of solid waste (trash) is an inevitable consequence of human life. Since the industrial revolution, waste disposal has become an increasingly pressing problem. Based on data from the U.S. Environmental Protection Agency (U.S. EPA, 2001), each person in the United States generated 4.5 pounds of solid waste per day in 2000. On average, one pound of this waste was recycled, 0.3 pounds was composted, and the remaining 3.2 pounds was discarded.

The U.S. EPA has outlined an integrated waste management hierarchy that consists of the components listed here, in order of preference:

- Source reduction — including reuse of products, backyard composting.
- Recycling — including community composting and recycling programs.
- Disposal — including incineration and landfilling.

Despite the growing emphasis on source reduction and recycling, in 2000 a large proportion — 162 million tons — of the solid waste generated in the United States was landfilled.

History of Landfilling

In the 1920s and 1930s, sanitary landfills were first constructed to replace the open dumps that posed, and some continue to pose, significant threats to human and environmental health. These primitive landfills were, literally, naturally occurring depressions in the landscape that were filled with waste and then covered with a minimum amount of soil. Sand and gravel pits and borrow areas were also commonly filled to form primitive landfills. Modern landfills, in contrast, are highly engineered containment systems, designed to minimize the impact of municipal solid waste (MSW) on the environment and human health.

In modern sanitary landfills, the waste is isolated from the ground water by a liner system, and rain water is prevented from entering the waste by a landfill cap (Figure 1). This method of *dry-tomb* landfilling minimizes the potential environmental impact of the leachate by reducing the generation of leachate and containing the leachate within the landfill. Leachate is water that has moved through the landfill and collected water-soluble compounds from the waste. If leachate migrates from the landfill and contaminates the surrounding soil and ground water, it can pose a risk to human and environmental health.

This dry-tomb method of landfilling is primarily a storage method for solid waste. The storage of solid waste in this manner requires land-use restrictions and continuing maintenance. In the absence of perpetual maintenance, landfill caps may fail, allowing the infiltration of rain water and the subsequent uncontrolled generation of leachate. If the liner system also fails, this leachate could pose serious health risks to the community and the environment.

What Is a Bioreactor Landfill?

A bioreactor landfill changes the goal of landfilling from the storage of waste to the treatment of waste. A bioreactor landfill is a system that is isolated from the environment and that enhances the degradation of refuse by microorganisms. Microbial degradation may be promoted by adding certain elements (nutrients, oxygen, or moisture) and controlling other elements (such as temperature or pH). The most widely used and understood method of creating a landfill

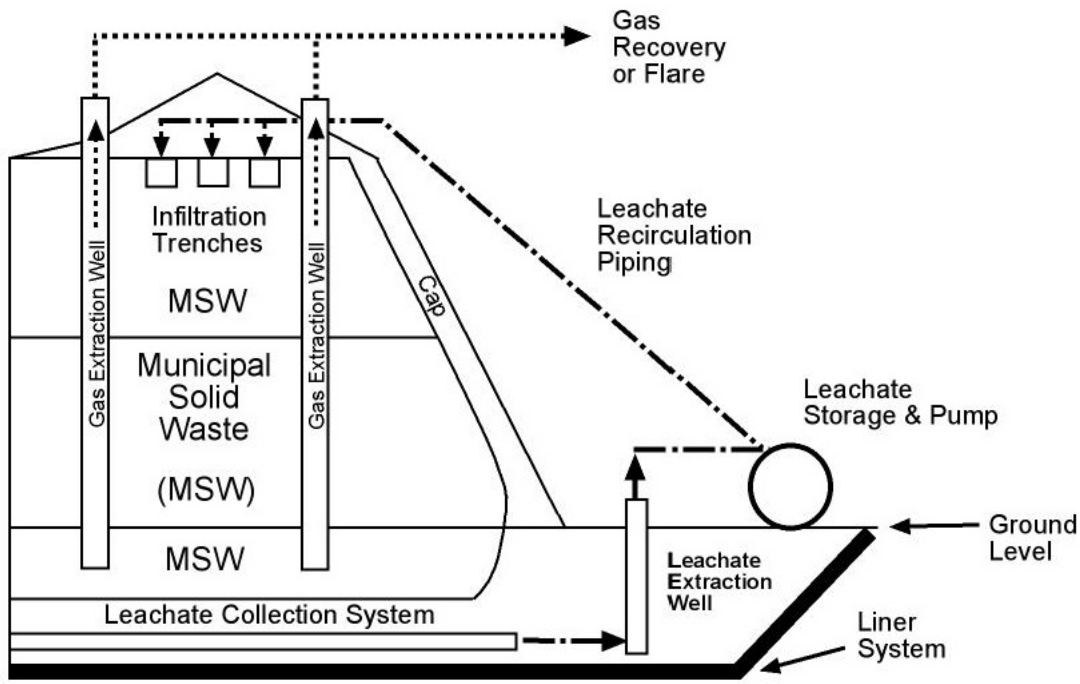

Figure 1: Schematic of a bioreactor landfill using leachate recirculation.

bioreactor is the recirculation of leachate, since the element that usually limits microbial activity in a landfill is water. The recirculation of leachate increases the moisture content of the refuse in the landfill and, therefore, promotes microbial degradation. If leachate recirculation alone cannot raise the moisture content to levels at which microbial growth is enhanced (40% by weight, minimum), water may need to be added to the waste.

Advantages of Bioreactor Landfills

Stabilization and Settlement

In a bioreactor landfill with leachate recirculation, there is a much faster decay or degradation of the waste due to the continual flow of the leachate through the waste. The enhanced speed and degree of microbial degradation in a bioreactor landfill results in more of the organic matter in the waste being transformed into water and gases (including methane and carbon dioxide). Once no further degradation of the waste can occur, the refuse is said to be stabilized.

In a sanitary landfill, stabilization may never occur, or it may take up to 100 years by some estimates. In a bioreactor landfill, stabilization should occur within 10 years or less. Because waste degradation results in the settling of the refuse as gas is released from the landfill, space becomes available within the landfill — space that can then be filled with more solid waste. The opportunity to add more waste extends the working life of the landfill and delays the need to construct new landfills.

Gas Production

The enhanced extent of degradation in a bioreactor landfill also speeds up the production of landfill gas and increases the total amount of gas produced. Landfill gas consists mainly of carbon dioxide and methane, with trace amounts of other gases. These gases are formed as a result of microbial degradation of waste components. The increased methane production makes it more economically feasible to use the methane generated within the landfill for heating or electricity generation. The capture and use of the methane reduces the negative impact of this greenhouse gas on the environment.

Leachate Quality and Environmental Impact

Recirculating leachate through the waste partially remediates, or reduces the toxicity of, the leachate. Each time the leachate passes through the waste, compounds within the leachate are transformed by microorganisms within the landfill, and the toxicity of the leachate is reduced. Once stabilized, the landfill poses less risk to the environment and community.

Current Status of Bioreactor Landfills

Authorizing Legislation and Codes

Minimum standards for municipal solid waste (MSW) landfill design, construction, and operation are regulated by Subtitle D of the federal Resource Conservation and Recovery Act of 1976 — called RCRA — under Title 40 of the Code of Federal Regulations, Part 258 (40CFR258). Leachate recirculation is allowed, and RCRA has been interpreted as allowing the addition of uncontaminated water to landfills that were designed and constructed using Subtitle D guidelines. Recirculating leachate produced in the landfill is rarely sufficient to raise the water content of the refuse to levels at which microbial activity is promoted. The U.S. EPA can issue special research, design, and development (RD&D) authorization permits to allow other additions of liquids to a bioreactor landfill.

Studies of Bioreactor Landfills

Laboratory studies demonstrated the potential benefits of bioreactor landfill technology as early as the 1970s. Pilot- and full-scale experiments began to be conducted in the 1980s and 1990s. Today, research continues, and several full-scale trials are being conducted across the United States.

For More Information

The sources listed here provide additional information on bioreactor landfills:

Hughes, K. L. and Christy, A. D. 2003. Bioreactor Landfills. In: *Encyclopedia of Agricultural, Food, and Biological Engineering.* Marcel Dekker, New York, N.Y. 104-107.

Reinhart, D. R. and Townsend, T. G. 1998. *Landfill Bioreactor Design and Operation.* Lewis Publishers, Boca Raton, Fla.

Reinhart, D. R., McCreanor, P. T., and Townsend, T. G. 2002. The bioreactor landfill: Its status and future. *Waste Management and Research* 20, 172-186.

Vesilind, P. A., Worrell, W., and Reinhart, D. R. 2002. *Solid Waste Engineering.* Brooks/Cole, Pacific Grove, Calif.

U.S. Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 258, Subtitle D, Criteria for Municipal Solid Waste Landfills.

U.S. Environmental Protection Agency, 2001. Municipal Solid Waste in the United States: 2000 Facts and Figures. EPA-530-R0-2001. **http://www.epa.gov/epaoswer/non-hw/muncpl/report-00/report-00.pdf**

Other Related OSU Extension Fact Sheets in this series:

OSU Extension Fact Sheet CDFS 106-05, *Integrated Solid Waste Management.*

OSU Extension Fact Sheet CDFS-138-05, *Landfill Types and Liner Systems.*

OSU Extension Fact Sheet CDFS-137-05, *Landfills: Science and Engineering Aspects.*

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