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Landfills: Science and Engineering Aspects

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What Is a Landfill?

Almost every human activity produces solid waste — refuse, garbage, or trash. 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. Despite the current emphasis on recycling and reuse, more than half of this waste is disposed of in landfills. Given the current generation rates of solid waste in the United States, the land required to accept the waste generated by a community of 10,000 people in a single year is a one-acre area containing an eight-foot-deep pile of refuse.

Guidelines for municipal solid waste (MSW) landfills were first issued in 1959 by the American Society of Civil Engineers. These landfills were constructed to replace open dumps, which posed a significant health threat to the environment and the community. Modern landfills are highly engineered containment systems, designed to isolate the solid waste from the environment and minimize the environmental impact of that waste. A schematic of a modern landfill is shown in Figure 1 on page 2.

Different types of landfills are constructed to be the ultimate disposal sites for different types of wastes. Construction and demolition debris (C&DD) landfills are built for the disposal of asphalt, shingles, wood, bricks, and glass. Municipal solid waste (MSW) landfills are used for the disposal of residential, non-hazardous commercial, and non-hazardous industrial wastes. Secure landfills are the final disposal option for treated hazardous wastes that once were flammable or toxic wastes.

This fact sheet focuses on the siting, construction, operation, and closure of municipal solid waste landfills. Fact Sheet CDFS-138-05, *Landfill Types and Liner Systems,* gives a more detailed description of all three types of landfills and the different liner systems required for them.

What Happens to Solid Waste Inside a Landfill?

Trash contains organic material (paper, food, and yard waste) that may be broken down (biodegraded) by microorganisms within the landfill. In the presence of oxygen, aerobic microorganisms break down the organic materials in the landfill, producing carbon dioxide and water. When the oxygen has been used up, the remaining components are degraded by anaerobic microorganisms. Landfills contain a complex community of anaerobic microorganisms, and each one contributes a step, or steps, to the degradation of refuse to produce methane, carbon dioxide, and water. The combination of gases formed during degradation is called landfill gas. The exact time needed to produce landfill gas depends on the specific conditions within each landfill.

The rate of microbial degradation of refuse is determined by the temperature within the landfill, the composition of the refuse, the presence of compounds toxic to microbial growth, and the availability of water. In most MSW landfills, degradation usually occurs very slowly due to the lack of water, taking place over several decades. In many landfills, only minimal degradation is observed, and the landfill, therefore, acts as a long-term storage site for refuse.

Water that was present in the refuse when the refuse was placed in the landfill, and any rain that enters the landfill during operation, passes through the landfill and absorbs organic compounds, metals, and ions (for example, nitrate and sulfate), from the refuse components. This liquid is referred to as landfill leachate. If leachate is allowed to escape

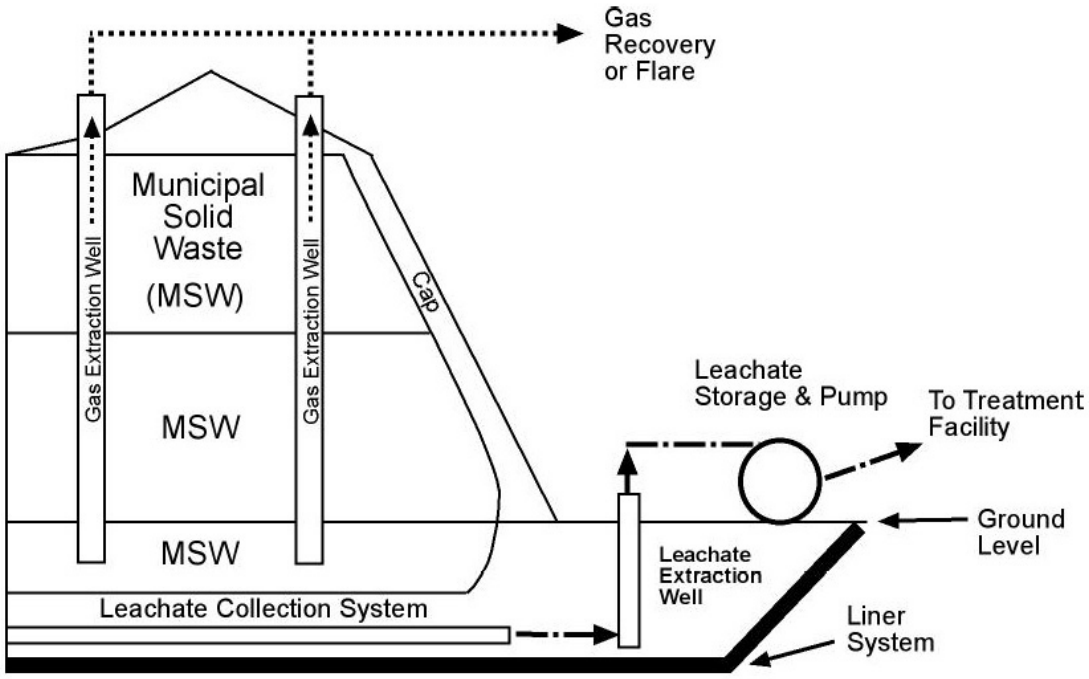

Figure 1: A modern landfill.

from the landfill without treatment, it poses a potential risk to the environment and human health.

Physical and chemical reactions that occur within the landfill include the suspension and precipitation of some compounds into the leachate and the evaporation of organic compounds into landfill gas.

As a result of the chemical and biological degradation of refuse, some of the organic components in the refuse are transformed into landfill gas. These gases either leave the landfill by passive diffusion or are extracted by a gas collection system installed in many modern landfills. The production and release of these gases reduces the volume of the refuse in the landfill. The remaining refuse in the landfill settles, to fill in the pockets left behind by the degradation process.

How Is a Landfill Sited?

Landfill siting is an issue that concerns the community. Potential landfill sites must be carefully screened to ensure that the chosen site meets all engineering, geological, and regulatory specifications.

Prior to siting a new landfill, the volume of landfill space required for the community should be estimated. These estimates are made by considering the population size, predicted growth, and the amount of refuse generated per person in the community. The site chosen for a landfill should provide sufficient capacity to accept waste from the community for up to 30 years to make the investment economically feasible. And there must be space adjacent to the landfill site for offices, leachate and gas treatment, and recycling facilities, if appropriate.

Potential sites for a landfill must meet a series of criteria laid out in federal (Subtitle D of the Resource Conservation and Recovery Act, 40CFR258 Subpart B), state (Ohio Administrative Code 3745-27), and local regulations. Federal regulations restrict the siting of a landfill to areas that are not in, or near, airports, floodplains, wetlands, or zones of geologic instability — faults or the potential for earthquake activity. Regulations in the Ohio Administrative Code prohibit the siting of landfills in, or near, national and state parks, aquifer systems and ground water used as drinking water sources, residences, and surface water. In addition to federal and state restrictions, landfill siting must also comply with local regulations that are specific for each community.

Because a landfill is constructed as the final disposal site for refuse generated by a community or communities, for economic reasons it is preferable that the landfill be readily accessible to the community or communities that it serves. If a landfill is sited at a great distance, the expense of hauling refuse to the landfill becomes a major consideration and a financial burden.

Once a potential site is selected, the company, municipality, or county that is to construct and manage the landfill submits a permit-to-install application to the director of the Ohio Environmental Protection Agency (Ohio EPA).

This permit contains engineering plans and specifications. The site selected for the landfill must meet all appropriate federal and state regulations. Copies of all paperwork must be submitted to the Board of Health in the district, or county, where the landfill is to be sited.

Within 35 days of submitting the permit-to-install, an applicant's meeting must be held in the county where the proposed facility will be sited, or in adjoining counties. The public must be given 30 days notice of these public meetings in a newspaper that is widely circulated in the county in which the proposed facility is to be sited. At the applicant's meeting, the operator of the proposed facility must describe the proposed facility and respond to written and oral questions posed about the facility.

An information session must be held at least 14 days before a public hearing. At this information session, an Ohio EPA employee will describe the status of the permit application. Further requirements for the public hearing process are documented in Revised Code 3734-05. After a draft permit is issued, the Ohio EPA conducts a public hearing to obtain comments on the permit application and draft permit. A 30-day comment period is available after the public hearing for written comments. For more information on public participation in the siting of Ohio landfills, see: **http://www.epa.state.oh.us/pic/facts/pub.html**.

How Is a Landfill Constructed?

Landfill site preparation includes grading the surrounding land to reduce water runoff into the landfill, constructing access roads, and installing fences to secure the area. Modern landfills are constructed in sections. The first area to be filled is excavated, and the base is graded to enable the collection of water and leachate within the section. The sides are sloped, and a liner system is installed that covers the bottom and sides of the excavation. The liner is a series of protective layers that prevent leachate from leaving the landfill and contaminating nearby ground water.

Within the liner system are perforated collection pipes that remove leachate from the landfill (Figure 1). The leachate may either be treated on-site or transported off-site for treatment. For more information on landfill liner systems, see Fact Sheet CDFS-138-05, *Landfill Types and Liner Systems*. During the operational life of the landfill, additional sections will be excavated as necessary.

How Is a Landfill Operated?

Waste is deposited in layers, called *lifts,* within the landfill and above the liner system. As waste is deposited, it is compacted by heavy machinery to maximize the amount of refuse that can be disposed of in the landfill. At the end of each day, the waste is covered with a thin layer of soil or alternate covers, such as specialized plastics, textiles, or tarps. This daily cover restricts the amount of windblown debris, odors, rodents, and insects on the site and controls fire hazards. Daily cover can also minimize the amount of rain water that enters the refuse. By keeping the water content of the refuse low, traditional landfills reduce the amount of degradation that occurs and, therefore, the production of leachate is reduced. Minimizing the volume of leachate minimizes the potential for leakage and, therefore, reduces the threat to the environment posed by the landfill.

Once one or more lifts of refuse have been deposited above the liner, gas collection tubes are placed within the landfill. These pipes are used to collect the landfill gas. Over the lifetime of the landfill, lifts will be added until the landfill meets the permitted height.

Landfills are extensively monitored. The chemical composition of leachate is regularly analyzed, and the amount of leachate present above the liner is maintained below a mandated depth to minimize the possibility of leaks. If too much leachate is detected on the liner, the collection system pumps leachate from the landfill. This leachate is collected and treated to prevent an adverse impact on the environment.

Ground water around the landfill is monitored to ensure that the liner and leachate collection systems are operating correctly. A system of wells is installed around the landfill. These wells are used to detect inorganic and organic compounds in the ground water that may indicate a leak in the landfill liner. An air quality monitoring system ensures that the gas collection system at the site is adequately capturing the landfill gas generated on the site.

Federal regulations require that rain water must be prevented from draining into the excavated landfill. This is achieved by directing rain water off-site and routing rain water that falls on-site to sedimentation ponds. Discharge from these ponds is also monitored.

Landfills that are permitted for municipal solid waste (MSW) must develop a method of preventing the disposal of hazardous wastes in the landfill. A plan is established for the separation and disposal in a licensed facility of any hazardous waste that mistakenly enters the landfill. Other operational issues that must be considered by landfill operators include restricting public access to the landfill, controlling traffic on the landfill, providing appropriate safety equipment to landfill personnel, and ensuring structural stability of the landfill.

How Is a Landfill Closed?

Once a landfill has been filled, it must be closed according to federal and state regulations to minimize the long-term impact of the landfill on the environment. The landfill is

covered with a final cap that is designed to minimize the amount of water that can enter the landfill (Figure 1). The cap may contain a gas collection system, especially at larger sites. Landfill gas that is collected is piped to a flare where it is burned or used to generate electricity. The cap usually has an uppermost layer of soil; that layer allows revegetation of the site and ultimately facilitates future reclamation of the site.

Federal and state regulations stipulate that monitoring and care of the landfill site must continue for at least 30 years after the landfill ceases to receive refuse. The depth of leachate on the liner continues to be controlled during the postclosure period. Excess leachate is removed from the landfill and treated. Ground water around the landfill is monitored to detect any leaks in the landfill liner. Air quality is evaluated to ensure the gas collection system is adequate. The grass on top of the cap must be periodically mowed to prevent the puncture of cap layers by tree roots. During the postclosure period, the landfill must undergo periodic inspections to ensure that the cap, liner, and collection systems are in good condition.

What Is the Future of Landfills?

As the design, operation, and management of landfills have improved, the environmental impact of our waste is reduced. The final issue for a closed landfill is the future of the land. The incorporation of engineering safeguards into landfill design is facilitating the reclamation of closed landfills for community use. Several closed landfills have been successfully converted into community green space, recreational areas, golf courses, and commercial, industrial, and residential uses.

There is also the option of mining landfills. In landfill mining, the landfill is excavated, and the fill is processed to recover potentially valuable products. This processing involves mechanical separation procedures. Landfill mining was first used in 1953 in Israel to recover a soil amendment from a landfill. Landfill mining may recover recyclable materials, valuable minerals, combustible fractions, soil, and, thus, landfill space.

In addition to finding uses for the closed landfills in our communities, there are also alternate operating schemes for existing and new landfills. One promising technology is bioreactor landfill technology. A bioreactor landfill is a landfill in which the conditions within the landfill are optimized for microbial degradation. Enhanced microbial degradation results in enhanced gas production and settlement. The accelerated settlement provides the opportunity for landfill space to be reused and reduces the need for new landfills (Fact Sheet CDFS-139-05, *Bioreactor Landfills).*

Conclusion

As our understanding of landfill processes has improved, we have been able to improve the level of environmental protection that is engineered into these facilities. Modern landfills — if sited, constructed, and operated appropriately — no longer pose a significant risk to the environment. As long as we, as a society, continue to produce solid wastes, it appears that we cannot live without landfills. We can, however, improve these facilities and the methods of dealing with the solid waste that we generate. As we explore alternate end uses for existing landfills, it may be possible that closed landfills will add value to our communities.

For More Information

The sources listed here provide additional information on municipal solid waste landfills and landfill regulations:

Code of Federal Regulations. Title 40, Part 258 Subtitle D, Criteria for Municipal Solid Waste Landfills.

Ohio Administrative Code. Chapter 3745-27. Solid and Infectious Waste Regulations.

Tchobanoglous, G., Theisen, H., and Vigil, S. 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues.* McGraw-Hill, Boston, Mass.

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

U.S. Environmental Protection Agency. 1994. *Design, Operation, and Closure of Municipal Solid Waste Landfills.* EPA/625/R-94/008.

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-139-05, *Bioreactor Landfills.*

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