The Role of Landfills in the Hierarchy of Waste

While the least-preferred option in the solid waste management hierarchy, landfills are nonetheless an integral part. This article provides an update on the role of landfills in today’s sustainable waste management strategies.
The U.S. Environmental Protection Agency (EPA) and other environmental agencies and organizations have rightly devised a hierarchy for the management of non-hazardous waste materials (i.e., municipal solid waste or MSW). The goal of the hierarchy is to limit the volume of material that ultimately reaches a landfill. Eliminating waste is a noble goal, and one that we all should try to achieve. However, until that goal is fully achieved, landfills will remain the foundational component of the waste management hierarchy.

As shown in Figure 1, the waste management hierarchy starts with reducing the source of MSW, followed by reusing, recycling, and/or recovering materials. This materials management approach is being adopted in numerous states and by corporations as part of their sustainability practices. The hierarchy ties well with the “zero waste” concept and product stewardship, which promotes a philosophical and economic shift in society behavior and in the marketplace. Unfortunately, philosophical and economic shifts take time to transpire. Therefore, until such time when our waste or residuals can be reprocessed, reformulated, or composted or otherwise beneficially used in a way that produces another usable and needed product, there will be a need for MSW disposal, and hence, environmentally sound and efficiently operated landfills.

At present, there is a growing trend to divert MSW from landfills, and municipal governments and waste management firms are involved in educating the public on best practices to do so. Some municipalities have instituted “Pay As You Throw” programs to promote MSW reduction; there are regional waste-to-energy facilities that significantly reduce the volume of MSW while extracting energy from waste combustion; and some states have legislated waste diversion and minimization programs, including bans on landfilling organics (primarily, food waste). Despite current efforts, there are materials that fall through the reduce-reuse-recycle-recover rungs of the hierarchy.

Complying with the more appealing aspects, or upper rungs, of the waste management hierarchy is hindered by a number of factors, that result in the continued generation of rubbish requiring disposal, and hence, the need for landfills. Factors that lead to the generation of disposable waste include product marketing and packaging practices for consumer goods, the prevalence of single-use items, material contamination (e.g., recyclables coated in food waste), and market pricing (i.e., the cost to recycle/reuse significantly exceeds the cost to dispose). Accordingly, today’s society needs to rely on landfills, not just to serve as the final repository for unusable materials, but to serve as the foundation of the waste hierarchy. Landfills act as the catch-all for materials that are filtered through the waste pyramid and have nowhere else to go. Without them, the waste management pyramid crashes down on itself.

**Landfill Design**

Since the promulgation of federal MSW landfills rules (40 CFR 258 or RCRA Subtitle D) in October 1991, there has been public resistance to developing new landfills. The combination of state and local regulations, land use issues, and physical site constraints has required MSW landfills to be innovative in design and operation. The quest to permit a new MSW landfill can be a daunting task, and is a contributing factor to the inevitable disposal capacity crisis. It is more important now than ever that existing landfill facilities become sustainable through innovative design and operation.
The increased awareness of waste reduction has not eliminated the fact that unrecyclable and non-recoverable waste still needs to go somewhere. Existing and future MSW landfills are needed to provide for the never-ending need for disposal capacity, and the way to achieve this is through airspace optimization. Airspace, or volume available for disposal at a landfill, is the main driving factor behind a landfill's lifespan. Airspace also serves as a business metric for landfill operations, and, from both an environmental and business perspective, it is advantageous to prolong a landfill's lifespan. There are three phases of landfill airspace optimization: (1) engineering considerations, (2) technology integration, and (3) plan, monitor, and evaluate.

**Engineering Considerations**

Most people do not know the effort needed to plan and engineer an environmentally sound and efficiently operated MSW landfill. Landfills present engineers with a variety of challenges, including how to manage land use, traffic, liquids, and gases, as well as other environmental, civil, geotechnical, mechanical, and electrical engineering issues. As noted, one of the major goals of a landfill designer is airspace optimization. In this regard, designers look at the best way to utilize property setbacks, landfill depth, side slope geometry, perimeter berms, retaining walls, and road and drainage configuration, all while staying in compliance with strict federal, state, and local regulations.

The easiest approach to developing landfill airspace is by optimizing the horizontal and vertical limits. While there are restrictions to these limits, geosynthetic construction materials and innovative construction techniques can maximize the utility of the available space. As addressed below, additional airspace can be realized by accounting for waste settlement, a significant component of the overall design that is proportional to the height of the waste column. Operators can take advantage of waste settlement through waste filling sequence planning.

The exterior slopes of most landfills are inclined at 3 horizontal to 1 vertical. Knowing that MSW settles, it is feasible, with regulatory approval, to “overfill” the slope slightly in anticipation of the settlement. By increasing the side slope inclination by a small amount in anticipation of landfill settlement, as shown in Figure 2, operators can place more waste within the confines of the landfill.

Roadways and drainage terraces are often cut into a landfill slope, resulting in a loss of airspace. As shown in Figure 3, if these terraces were spaced more frequently or were wider, then the resulting lost airspace would be greater. One approach to optimizing airspace is to “tack on” roads and terraces. During the design process, owners and operators, working with the engineers, can evaluate the cost/benefit of this approach. We have found this approach to be economically beneficial, especially when the roads and terraces are constructed with materials that owners are paid to receive (i.e., dirty dirt).

**Technology Integration**

There is a history of published literature related to extending the life of a landfill through improved MSW compaction. The weight of the compactor, the type, number, and pattern of the teeth on the wheels, and the number of passes all influence the degree of compaction. In general, the more weight you can impart, and the better the waste is shredded, the better the compaction. When compacting waste, the thinner the lift the better, with most guidance indicating a loose layer thickness for deposited MSW of 2 to 3 feet. Also, the number of passes the compactor should make should be no less than three, but anything greater than five likely would not result in added value.
There are several manufacturers of GPS equipment for use in conjunction with operating landfill equipment. By using GPS, operators and managers can better control waste placement and compaction and reduce the need for periodic field surveys. By using the GPS devices, operators can achieve higher waste densities and reduce the loss of airspace because the information imported into the GPS is based on fill sequence plans. Managers can monitor filling and calculate waste density on a daily basis. All this reduces the potential for over- and under-filling slopes, and because the placement and compaction of the waste is more efficient, fuel consumption can be reduced.

Settlement of the waste allows landfill owners to resell airspace and prolong a site’s lifespan. Waste settlement can be promoted in several ways, all of which require some degree of planning. One common way to promote waste settlement, and potentially reduce other operational costs, is to recirculate leachate. It is well known that leachate recirculation accelerates the waste decomposition, which results in accelerated, and potentially greater, settlement. Because the waste settles faster, it is possible to recover the airspace gained sooner.

**Plan, Monitor, and Evaluate**

Landfill owners and operators can employ some basic systems to ensure that the available airspace is being consumed appropriately. Starting with a good baseline survey and having well-defined fill sequence plans, routine surveys of the landfill are essential to verify that the waste is being placed and compacted to the slope desired. As shown in Figure 4, a small difference in how waste is placed, if not identified early, can result in significant lost airspace, which can be expensive to recover.

MSW fill-sequence plans are useful in planning and scheduling how the landfill is operated, and estimating future capital expenditures for new landfill construction, landfill gas and leachate recirculation infrastructure, and landfill closure. The fill sequence plans also can be used to optimize landfill settlement. By operating the site such that the deepest areas of the landfill are filled first, more airspace can be gained over the life of the landfill.

By evaluating the results of routine survey and comparing the results to the fill sequence plans, owners and operations
can evaluate how well the airspace was utilized since the last survey. By comparing surveys and reviewing information related to the amount of waste received and the amount of cover soil used, we can calculate: the remaining airspace of the landfill, the in-place density of the waste, and the remaining life of the landfill.

Other Considerations
Because of the resistance to permitting new landfill sites from the general public and regulatory agencies, municipalities and private waste management companies have entertained the idea of digging up, or mining, old landfills to create new disposal capacity. Old, closed landfills that predate current solid waste regulations are typically unlined and contain large amounts of soil and recyclable material. By mining the old, closed landfills, these disposal areas can be repurposed as lined facilities, and the environmental issues caused by the past site use (i.e., groundwater impacts) can be mitigated. Also, it is possible that the materials recovered during mining may offset the excavation costs.

Takeaways
While the least-preferred option in the solid waste management hierarchy, landfills are nonetheless an integral part of that hierarchy. To the extent possible, the life span of existing and future landfills should be optimized to limit the need for future facilities, which can be difficult to permit. Designing MSW landfills are complex endeavors and involve numerous engineering considerations geared toward maximizing the landfill’s lifespan, while protecting human health and the environment. EM

Figure 4. Optimizing landfill airspace—accurate survey and fill placement.

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