Landfill Mining: Current Trends

Landfill mining is a term used to describe a process whereby landfilled solid waste is excavated and processed for beneficial purposes. BY BRUCE CLARK, ALYSON DAGLY, AND MARC ROGOFF

The beneficial purposes can include recovery of recyclable materials, recovery of soils for use as daily or intermediate cover in active landfills, or recovery of land area for redevelopment. As urban sprawl has continued in many metropolitan areas, landfills—which previously were located in areas relatively distant from the population centers—are less so, and the value of those properties for redevelopment have increased.

In the US, however, the term "landfill mining" has increasingly become a misnomer, as the primary driver has been to reclaim the old footprint and develop it to meet current Subtitle C regulations (i.e., typically at a minimum installing a bottom-lining system with leachate controls) and gain valuable additional airspace for active waste filling. The reclamation of recyclable materials—like plastics, metals, and glass, and plastics and paper for energy recovery—are secondary and do not typically justify the total cost to reclaim them with natural gas energy, both abundant and relatively "cheap."

As pointed out in the recent International Solid Waste Association (ISWA) publication on landfill mining, the concept of mining landfills is not new. Some 60 examples have been cited in solid waste literature since the first reported project in Israel in the 1950s. Landfill mining is a practice not unique to any particular country or even region. The practice has both advantages and disadvantages, which are summarized in Table 1.

Table 1. Landfill Mining/Reclamation Considerations

Advantages	Disadvantages
Gain additional airspace for active waste filling	Nuisances caused during mining (i.e., construction traffic, fugitive dust)
Recycling potential of certain materials	Potential presence of hazardous materials, extra cost and delays
Recovery of cover soil for reuse (if uncontaminated)	Escape of leachate and/or nuisance odors during mining operations
Potential for recovery of materials that could be used for energy production	Few regulatory laws or standards
Land reclamation	Projected volume of recyclables may not materialize
Remediation of soil and groundwater contamination	Relatively long process that requires Owner's oversight and management commitment

Planning Aspects

An overview of the entire landfill mining process is helpful to be able to properly plan all of the parts of the process and have contingency plans ready if something does not go according to plan. Table 2 presents a summary overview of the overall aspects to consider on a mining project.

What About Recyclables?

Some landfill owners have opted to separate and sell recyclables obtained from a reclamation project; however, the value of these materials is elusive. Cal Recovery, Hercules, CA, conducted a study for EPA of the Collier County, FL, landfill mining demonstration process in 1993, and concluded that plastic and metal were the only viable recyclables, but were not of acceptable quality for the resale market. They indicated that the actual "cost" of mining and separating the recyclables was about $115 per ton. Extrapolating that cost to today's dollars would cost approximately $250 per ton. This cost is high, relative to the price being paid for recyclables as discussed in the section on benefit-cost.

Construction Timeframe

Basic landfill mining equipment may include the following:

- Waste excavation: hydraulic excavators (backhoes)
- Waste screening (large objects): grizzly screen
- Waste screening (smaller objects): trommel screen
- Screen feed: front-end loader
- Waste hauling: dump trucks

The production of a landfill mining operation is mainly dependent on the size and number of pieces of equipment deployed, the types of soils used during landfill operations (e.g., sandy versus clayey materials), the types of waste disposed, weather conditions, liquid levels in the landfill, and gas emissions. More equipment means more production, but more equipment also means additional capital costs.

Certain types of waste are more difficult to excavate and process than others, which can slow productivity. High liquid levels and highly saturated wastes require additional steps to excavate and process, which, again, slows production. Inclement weather is a less controllable factor; however, the timing of major excavation efforts can be scheduled to take advantage of seasons with less inclement weather. Lastly, health and safety issues associated with gas emissions such as combustible gases, odorous gases, and such must be considered and can negatively impact surrounding properties if not controlled properly, ultimately impacting the excavation and processing activities.

Equipment involved in the waste excavation activities typically limits the actual capacity of an operation. This equipment

Table 2. Landfill Mining Planning Summary

Planning Element	Issues/Scope	Action Items
Baseline waste characterization	An accurate waste thickness profile and a representative description of the in-place waste of the waste is desirable.	A drilling and test pit program is usually necessary to obtain a reasonable understanding of the depth of the wastes and the main materials.
Soil and/or groundwater contamination	Can remediation be completed prior to constructing a new landfill cell?	Many proven new techniques are available that can relatively quickly remediate certain common types of contamination.
Special waste areas	Identify former areas used for disposal of asbestos, sludge, etc. Special health and safety issues will apply.	Develop a Contingency Plan for managing these wastes if encountered.
Materials desired for separation	Identify specific materials; soil, metals, plastics, etc. that are desired for reuse onsite (soil) or disposal offsite.	Large amounts of plastics could potentially go to a WTE plant. Soil should be tested if any concern it may be contaminated and unsuitable for reuse as daily cover.
Space required for relocated waste	Plan for waste disposal tonnage to your active cell to increase, potentially significantly, on a temporary basis, with refilling of some old waste.	Assume low volume of cover soil excavated and all other materials filled back into operating cell.
Space required for temporary storage of excavated cover soil	Ideally, the reclaimed cover soil should be transported from the screener directly to your current soil source area.	Some old landfills can contain up to 40% of cover soil. If soil has to be stored temporarily, a significant area could be needed.
Hazardous wastes	Always a potential to discover this, typically in drums. Special health and safety issues will apply.	Have a Contingency Plan for managing these wastes if encountered.

is involved in excavating compacted waste, loading trucks, and moving as the excavation progresses. The other machines in a landfill mining operation, such as shredders, screens, magnets, and conveyors are generally static (i.e., they are not moved for periods of time), and are processing materials that have had some loosening and separation, and are for one function only, so their capacity usually does not limit the operation.

If you are considering implementing a landfill mining project, you should be realistic about the time it will take to complete the project. This timeline needs to coordinated with the overall landfilling activities of a site, assuming it's an active landfill, and remaining site life calculations. A mining project and the necessity to dispose of much of the excavated materials back into the new landfill can temporarily increase the landfill tonnage by up to 80% over your normal throughput, if everything except the cover soils are put back in the landfill.

Take for example, an old landfill 40 feet high with a base dimension of 800 feet long by 500 feet wide, about a 9-acre footprint. That landfill will contain approximately 383,000 cubic yards of material. Working with three large bucket excavators (total bucket capacity 36 cubic feet), it would take at least a year, or more, to complete excavating, working nine hours a day, 6 days a week, without bad weather delay.

The most efficient approach is to stockpile recovered soils near or with other onsite cover stockpiles in order to handle the materials only once. However, this approach may not always be feasible. If that is the case, all of the mined soil may have to be temporarily stockpiled separately. Soils can make up to 40% of the materials mined from old landfills. In our previous example, that would amount to approximately 153,000 cubic yards of soil, which would be equivalent to a 4-acre stockpile area 40 feet high.

Benefit–Cost Assessment

A benefit–cost assessment should be conducted to justify pursuing a landfill mining project. One way to approach a benefit–cost assessment is to compare the estimated cost of mining the landfill cell against the value of the "new" airspace that created by mining and used for future landfilling (Table 3), or the value of the reclaimed property. We typically would not include the value of any separated recyclables, because the value of these recovered materials generally is inconsequential.

Table 3. Projected "Value" of New Airspace

Item	Amount
Total volume	383,000 CY
Less reclaimed soil = 20%	76,600 CY
Less all other materials = 42%	160,000 CY
Net new airspace	146,400 CY
Volume new waste at 1,400/CY	102,500 tons
"Value" of new airspace at $42/ton	$4,305,000

Table 2 summarizes a simple cost analysis for an example landfill mining project at an active landfill based on the following assumptions:

- Landfill cell volume = 383,000 yd^3.
- Volume of reclaimed soil = 20% of volume, and it will be reused as cover soil in the active landfill.
- Remaining materials excavated = 42%, and is disposed in adjacent active landfill.

If we further assume that the landfill is reclaimed at an average cost of $4 per cubic yard, then the reclamation cost (383,000 yd^3 x $4 per cubic yard) is equal to $1,532,000. Clearly, in this example, the reclamation benefit far outweighs the cost. If cover soil has to be purchased from an outside source, there could be another savings benefit by reusing the recovered soil. At higher tipping fees, the benefit gets even better.

Looking again at the potential value of recyclables, in this case plastics, the market price paid for plastics is down. If the plastics were of a quality to be acceptable on the market, at a price of 12 cents per pound, the value of the recyclable plastic is $240 per ton. Contrasting that to $250 per ton for mining and separation extrapolated from the Collier County study, plastic reclamation would not provide any significant monetary benefit.

Case Studies

Perdido Landfill

A pilot study was performed in 2008 that involved the excavation of 2.5 acres of an unlined cell at the Perdido Landfill in Escambia County. The main goal of the project was to acquire air space for future disposal.

Excavated waste was processed the following ways:

- separating the waste with a shaker screen following shredding,
- utilizing a shaker screen without shredding, and
- using a trommel screen for screening.

After field testing was conducted, it was found that the trommel screen proved to be the most effective at separating the waste from the cover soil, with waste shredding being the most time consuming of the three.

Soil constituted approximately 70% of the unlined cell. This recovered soil was stock piled at the site to be used at a later date for cover material. The excavated refuse was returned to the landfill for disposal. In regard to cost benefit analysis, the project proved to be worth the investment. The value of the acquired airspace outweighed the mining costs themselves. The total cost of mining was $8.60 per yard with a total of 54,000 cubic yards being excavated, 38,000 cubic yards of which was reusable cover soil.

Naples Landfill

The Collier County Solid Waste Management Department was involved in managing and performing a landfill mining project at the Naples Landfill in 1986. This was one of the first landfill recovery projects to occur in the US. No federal or state regulations regarding landfill mining were in place when the project began. At the time, the site was an unlined 33-acre MSW facility.

The three main goals of the project were to: (1) determine if an alternative method to traditional landfill closure was available and more economically feasible, (2) develop a low-cost system to separate the waste, and (3) provide performance data for this system to assist with optimizing the design of said waste processing system. However, the main underlying premise of the project was to reuse the soil portion within the waste mass since cover soil was relatively expensive and limited in the area. At the completion of the project, the site had successfully mined 5 acres of waste and was able to utilize the recovered material for cover, as it showed high levels of decomposition.

In total, 292 tons of waste were processed, with 171 of those tons reusable as cover soil. The waste was excavated at a cost of approximately $115 per ton. In regard to funding, the project received the "Innovations" award from the Kennedy School of Government at Harvard University; therefore, much of the project cost was covered by the award funds. The total cost to the County for this project was only $40,000. Without the award funding, a similar project is estimated to have a total cost of $1.2 million.

Frey Farm Landfill

In 1990, a municipal solid waste combustor (MWC) was constructed by the Lancaster County Solid Waste Authority in Lancaster, PA. The WTE facility had available capacity when built, which was filled through landfill mining and then spot waste until Lancaster County grew into the plant's full capacity. Since the waste in the lined landfill was less than five years old, a landfill mining project was a viable option for them. The facility was to utilize a mixture of new waste and reclaimed waste from the landfill as its augmented MWC input stream.

The waste was excavated from the landfill and processed using a 1-inch trommel screen. Approximately 56% of the excavated material from the landfill was acceptable for intake at the MWC, with 41% being composed of soil. Only 3% of the total excavated material was neither combustible nor able to be used as cover soil at the landfill, and had to be returned back into the landfill for disposal.

In order for the input wastestream of the MWC to achieve the necessary energy value, it had to be composed of 75% new waste and 25% reclaimed mined waste. While the project itself was cash flow neutral (revenue gains versus expenditures), it resulted in added value of reusing dirt for cover and reusing the cubic yard landfill space a second time. Once those assets were factored in, the overall gain was positive $13.30 for every ton of material excavation.

Lessons Learned

Some of the lessons learned over the last few decades from landfill mining in the United States include:

- Personnel and equipment typically assigned to normal landfill operations generally have the skills and capabilities to perform landfill mining activities, assuming they are available, but if not, these activities can be contracted out to experienced contractors.
- If there is soil and groundwater contamination under the landfill, sufficient time should be allocated in the schedule to remediate the area, preferably before re-lining and filling of waste.
- The quality of recyclables in old landfills (say something more than 10 years old) is questionable for sale in the marketplace. Unless there are extenuating circumstances (i.e., like those of the Frey Farm mining project), the cost of separating recyclables will likely be higher than the potential revenue from the marketplace.
- One needs to be realistic and conservative about the timeframe needed to mine an old landfill. Contingency delays for bad or seasonal weather, equipment breakage, or uncovering hazardous materials should be included in the schedule.
- There are many good case histories of landfill mining in the US that can be reviewed to become familiar with many of the variables that were encountered, costs, equipment, and how well the particular project went.

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