WRF Technical Brief:

Landfill mining

Introduction

Landfill mining and reclamation (LFMR) is a process whereby solid wastes which have previously been landfilled are excavated and processed.

Processing typically involves a series of mechanical processing operations designed to recover one or all of the following: recyclable materials, a combustible fraction, soil, and landfill space. In addition, LFMR can be used as a measure to remediate poorly designed or improperly operated landfills and to upgrade landfills that do not meet environmental and public health specifications (1). Typical equipment used in simple LFMR operations are excavators, screens, and conveyors. Complex LFMR operations recover additional materials and improve the purity of recovered materials, and therefore have equipment in addition to that of simple operations.

History

Landfill mining was first described in 1953 in an article that documented the processes used at a landfill operated by the City of Tel Aviv, Israel (2). The primary objective was to excavate the waste for the recovery of a soil amendment. The excavation equipment consisted of a front-end loader and a clamshell, and the processing equipment included several conveyors and a rotating trommel screen. The screen was about 7 metres long, 2 metres in diameter and rotated at about 13 rpm. The screen had openings of approximately 2.5cm.

In the process, waste material was excavated and transported to a conveyor belt. The conveyor belt transferred the waste to the trommel screen. Material that passed through the screen openings was used as soil amendment, and material that was retained in the screen was taken by conveyor belt to a resource recovery area where manual separation was used to recover ferrous metals and other recyclable materials.

In the Tel Aviv LFMR project, the soil amendment had a total nitrogen, phosphorous, and potassium (NPK) concentration of 1.4%. The soil amendment was used primarily in citrus groves; due to the relatively high concentration of broken glass, the material was not used in other agricultural applications. According to the literature, the operation in Tel Aviv remained the only application of LFMR until the 1980s.

Two developments took place in the USA between 1950 and 1980 that impacted on landfill mining. One was the emergence of a modular processing system designed to process mixed waste as it arrived at landfills or at transfer stations, primarily for the purpose of recovering steel containers. The second development took place in the late 1960s/early 1970s, and dealt with an assessment of the technical feasibility of composting landfilled municipal solid waste (MSW) *in situ*. The project involved the construction of especially designed cells in a landfill. Some of the cells were filled with sorted MSW and other cells with mixed MSW, and covered with a soil layer. A forced aeration system was set up to supply other cells with mixed MSW, and covered with a soil layer. A forced aeration system was set up to supply the oxygen for the process.

The project was not implemented at full-scale because of the lack of technical feasibility. In addition, several fires in the cells were attributed to spontaneous combustion. Although the project was not adopted, it provided information on the acceleration of the degradation of organic matter in a landfill as well as emphasised the importance of a cellular structure in a sanitary landfill (3). The modular concept of processing wastes at disposal facilities, in conjunction with *in situ* processing of landfilled wastes, has become the basis of many current and planned LFMR systems.

In 1982, a proposal was made to the Metro Manila Commission in the Philippines (4). The proposal called for the application of landfill mining in the upgrading of one of Metro Manila's disposal sites on the Island of Balut, Tondo. However, the project was not implemented, primarily due to a shortage of funds.

Status of landfill mining

Limited information is available on landfill mining projects that have been carried out on a worldwide basis (5-9).. However, it has been reported that LFMR projects have been planned or implemented at the Non Khaem Landfill in Bangkok, Thailand, and at the Nanjido Landfill serving metropolitan Seoul, Korea. In the United States, only six landfills have been mined. The following brief descriptions of some US projects and their results serve to illustrate the variety of reasons for considering and implementing LFMR operations, and to illustrate operating experiences.

Collier County, Florida

A comprehensive field test evaluation of the Collier County landfill mining system was conducted in 1992 under the US EPA's Municipal Innovation Technology Evaluation (MITE) Program. The complex LFMR system was operated by the County as a demonstration. The mined wastes were relatively well decomposed. The soil fraction recovered from the process (ie cover material plus fine decomposed wastes) accounted for about 60% of the infeed material. With the exception of the soil fraction, the degree of purity of the recovered materials was in the order of 82% or lower. Thus, the ferrous and plastics fractions contained substantial levels of contamination that would probably impact their marketability.

In the case of the soil fraction, the concentrations of metals were found to be below the limits imposed by the State of Florida for unrestricted use of waste-derived compost.

Barre, Massachusetts

As part of a permit application to expand a private sanitary landfill in Barre, Massachusetts, a proposal was made to mine a section of the property that had been filled between the mid-1950s and 1970. The sections to be mined would be lined prior to any additional filling.

Test pits were dug to evaluate the material that would be processed. Excavation showed that some of the cells had been constructed to be almost completely impervious to the external penetration of water. The contents of these cells showed little decomposition. The recovered soil fraction was retained for use as cover material.

Bethlehem, New Hampshire

The Bethlehem, New Hampshire landfill site served small towns and rural tourist areas. The soils beneath the site were generally glacial till. Between 1979 and 1987, landfilled wastes were covered with 1 metre of the site were generally glacial till. Between 1979 and 1987, landfilled wastes were covered with 1 metre of material as an interim closure measure for the fill.

In 1989, the company that owned the landfill was sold and the new enterprise filed a permit to expand the Bethlehem landfill. The expansion would include a double-lined landfill adjacent to the old, unlined one. The New Hampshire Department of Environmental Services (NHDES) required that approximately 160 tonnes of material be relocated from the old, unlined portion of the landfill to the newly lined section. As part of the relocation process, NHDES allowed the company to mine the unlined landfill. Once the plans were approved, the NHDES included various requirements in the permit to build the new landfill that pertained specifically to the mining operation. Among those requirements were stipulations regarding daily cover, leachate management, and the testing of soil and groundwater. Due to concerns regarding odours, the permit prohibited any mining or waste removal operations during June, July, and August and required that odour masking agents be applied to the wastes being processed.

Throughout the landfill mining process, the impacts on air quality and the quality of the storm water runoff were monitored. The monitoring process also included measuring the concentrations of oxygen, hydrogen sulphide, and volatile organics in the air. Water quality monitoring also focused on changes in conductivity and pH. Slight increases in conductivity were noted; no changes in pH were detected.

Equipment used consisted of two excavators, one front-end loader, four dump trucks, two bulldozers, one trommel screen, and one odour control sprayer.

Edinburg, New York

In 1988, the New York State Energy Research and Development Authority (NYSERDA) contacted more than 250 landfill owners and operators in the state to ascertain their interest in participating in a landfill mining demonstration project. The Town of Edinburg was subsequently selected by NYSERDA as the host site for a one-acre demonstration project. Edinburg is a small, rural community and has a relatively small landfill.

The objectives of NYSERDA in undertaking the Edinburg project were as follows:

- determine equipment needs and develop optimal procedures for the excavation, separation, handling, and storage of landfilled materials
- determine appropriate uses for the reclaimed material
- identify available markets for the materials
- develop required processing needs for the reclaimed materials
- develop recommendations regarding health and safety requirements
- conduct contingency planning for future landfill reclamation projects in New York.

Screening of excavated wastes was the significant key unit operation employed during the Edinburg LFMR project. Approximately 25% of the mined materials passed through a screen surface with 7.6cm openings and was retained on a screen surface with 2.5cm openings. This fraction consisted primarily of cans and bottles. The material larger than 7.6cm included plastics, textiles, paper, wood, and metal.

A test burn of a sample of residue from the LFMR process was conducted at the Pittsfield, Massachusetts waste combustion facility. The results of the tests indicated that the higher heating values for the residue varied between 4,700 and 5,800 kJ/kg.

Residue (ie material larger than 2.5cm) from the screening of materials during a hand sorting phase of the project was evaluated. The evaluation indicated that more than 50% of the rejects could be taken to a project was evaluated. The evaluation indicated that more than 50% of the rejects could be taken to a materials recovery facility (MRF) for recycling, although the excessive concentration of dirt in the LFMR residue could contaminate clean source-separated recyclables. White goods and scrap metal would require cleaning to remove soil, and then the material could be baled and sold. The assessment of manually-separated film and HDPE plastic indicated that these materials could also be sold.

Samples of materials were collected for analysis. No significant contaminant concentrations were detected during tests for asbestos, compost parameters, Toxicity Characteristic Leaching Procedure (TCLP) parameters, Target Compound List (TCL) parameters, and pathogens. Results of analyses indicated that the soil fraction met the State of New York standards for ClassÊI compost and qualified for off-site use in a variety of applications, including clean fill in public construction projects and daily landfill cover.

Lancaster, Pennsylvania

The Lancaster County Solid Waste Management Authority (LCSWMA) operates the landfill and transfer stations in the county. The Frey Farm landfill, located in Manor Township, was opened for waste disposal in September 1988. Construction of a three-train, massburn facility, with a design capacity of 1,100 tonnes/day, was completed in December 1990. Since the initial delivery of waste was less than anticipated, previously landfilled wastes were excavated from the first 18-acre landfill cell and added to fresh MSW as supplementary fuel for the massburn facility. Mined material is combusted with raw MSW in a ratio of about 1:3 (weight basis). Earlier tests using unscreened mined material required a ratio of 1:7 or 1:8 in order to maintain design conditions for combustion, due to the relatively low heating value of mined wastes. The facility yields about 660 kWh/tonne of raw MSW, based on a heating value of 12,200 kJ/kg. When mined material is combined with fresh MSW for combustion, the yield decreases to about 500 kWh/tonne of fuel burned. Ash yield from mined material is about 35%.

Combustion of mined MSW did not have a negative impact on the permits for either the resource recovery facility or the landfill. The Pennsylvania Department of Environmental Resources (PADER) monitors the mining.

Concerns initially expressed by PADER included the potential for changes to storm water runoff, extra leachate generation, and gas releases from the mining operation. However, none of the concerns became a problem. The only negative impact has been the additional traffic generated by the delivery of mined material to the project.

The LCSWMA's objective in landfill mining has been to minimise the area of landfill in use. The energy value of the mined material is estimated to be US $33/tonne. Material recovery is less attractive economically and, therefore, it is not a component of the operation.

Thompson, Connecticut

In 1986, the municipal landfill was due to close in the Town of Thompson, Connecticut. The Town initiated a landfill mining project with the objective of recapturing landfill volume and extending the life of the landfill temporarily while a permanent disposal alternative could be selected.

A local excavation contractor conducted the project, using a bulldozer, a pay loader, a truck, and a screen. The contractor first excavated about 20 test pits in the landfill. The area mined was a combination of the residuals from an old dump (which was set on fire periodically) and bulky wastes. No odours were detected as a result of the mining program. Waste decomposition was relatively incomplete in material that was 15 years old or less. This younger waste probably occupies areas where daily cover was initiated after the period of open burning. At the time of the mining project, the available disposal alternatives represented costs in the range of US$66 to US$88/tonne, plus transportation. The cost of the mining represented costs in the range of US$66 to US$88/tonne, plus transportation. The cost of the mining project was US$117,000, including grading the base of the mined area to receive new MSW. Representatives from the town estimated that the town saved US$1m in tip fees over an 18-month period.

Technology

Accelerated decomposition

The discussion on technology is prefaced by a paragraph on accelerated decomposition, because stability of buried organic wastes is essential to landfill mining and reclamation. Mining insufficiently decomposed wastes would result in an unacceptable generation of nuisances and negative impacts with regard to health and safety and the environment. Landfill mining should not be attempted before the landfilled wastes are sufficiently stabilised. This prerequisite and other factors related to management of a completed landfill have led to an increase in studies on accelerating decomposition of organic matter in landfills (10).

Technology design

Technology design centers on the attainment of the following two goals:

1. *excavate the landfilled material*
2. *process the excavated material such that target material can be separated from the excavated mass and further processed to fit its intended use or disposition.*

A third goal is introduced if the mining is intended to reclaim landfill capacity or to upgrade the landfill. In such a case, the portion of the landfill destined to be upgraded is excavated and processed as needed.

Excavation

The technology involved in the excavation of landfilled waste has not changed much since the Tel Aviv project in the 1950s. Generally, excavation is conducted using techniques similar to those used for open face mining. Equipment involved may be a front-end loader, a clamshell, a backhoe, a hydraulic excavator, or a combination of these. Excavated material either may be directly processed on-site or be stockpiled for later processing, either on-site or at a processing facility.

Processing

Processing begins with the segregation of the excavated mass into discrete streams. The number and composition of the streams depends upon the desire and extent of resource recovery. Excavated material is discharged into a coarse screen; and oversize, non-processible wastes are removed by the screen. The remaining fraction is transferred to another screen having relatively small openings. Material that passes through the screen openings (ie the under□size stream) constitutes the soil fraction. A trommel screen is an efficient unit process for separation of soil fraction from excavated waste. Material retained in the screen is removed and is exposed to a magnet to recover ferrous metals. The non-ferrous fraction is processed through an air classifier that separates light organic materials from heavy organics. As shown, air classification could be used to recover a waste-derived fuel.

At present, processing at the landfill site is typically accomplished by means of equipment mounted on trailers. The equipment usually consists of conveyor belts, a coarse screen, a fine screen, and a magnet. Useful products are soil which may contain stable organic matter and a low-quality ferrous fraction. The number of separated streams and the degree of processing involved depend upon several factors, not least of which is whether the separated material is to serve as a resource or is to be rendered innocuous (landfill of which is whether the separated material is to serve as a resource or is to be rendered innocuous (landfill remediation or upgrading). Other factors include those which determine economic feasibility and advisability, and market demand for the recovered materials.

Product characteristics

Amounts and characteristics of products recovered from a landfill are functions of the landfilled wastes. Those few values reported in the literature or cited herein must be regarded as being related to single instances, and may or may not be representative.

Recovery efficiency

The percentage recovery of a landfilled resource depends upon:

1. the physical and chemical properties of the resource
2. the effectiveness of the type of mining technology
3. the efficiency with which the technology is applied.

Judging from available information and mechanical processing efficiencies, recovery of soil could be expected to fluctuate between 85% and 95%, ferrous metals from 70% to 90%, and plastic from 50% to 75%. Purity of these materials could be expected to be 90% to 95% for soil, 80% to 95% for ferrous metals, and 70% to 90% for plastic. The higher percentage of purity for each material category would generally be attributed to relatively complex processing designs.

Feasibility

The types of materials recovered from an LFMR project are determined by the goals of the project, the characteristics of the landfilled wastes, and the process design. In a typical LFMR operation, once the oversize non-processibles, the dirt fraction, and the ferrous metals are removed, the remaining material may be recovered as fuel for a waste-to-energy facility, processed for recovery of other recyclables, or landfilled as residue.

The soil fraction recovered by mining typical landfilled MSW will probably comprise the largest percentage by weight of all materials; a range of 50% to 60% can be expected, although values from 30% to 70% have been reported. The ratio of soil to other materials depends upon the type of waste landfilled, landfill operating procedures, and the extent of degradation of the landfilled wastes. As mentioned earlier, in the Collier County, Florida demonstration project, about 60% (by weight) of all mined materials was recovered as a soil fraction.

The major difficulty in marketing mined materials is in producing the necessary high quality. Another obstacle is the limited number of waste-to-energy facilities in some areas to serve as a market for combustible materials.

Site-specific conditions will determine whether or not LFMR is feasible for a given location. Key conditions include:

- *composition of the waste initially put in place in the landfill*
- *historic operating procedures*
- *extent of degradation of the waste*
- *types of markets and uses for the recovered materials.*

The environmental and economic benefits of landfill mining include the following:

- use of recovered soil fraction as landfill cover material;
- recovery of secondary materials;
- reduction of landfill footprint and, therefore, reduction in costs of closure and post-closure; and
- reclamation of landfill volume for reuse.

Conclusions

Landfill mining and reclamation is a developing technology and method of waste management. Given its developmental status, only tentative conclusions can be drawn regarding LFMR potential, and prospects for fulfilling that potential.

The technology of LFMR can be effective in recovering landfill capacity for reuse for land-filling or for use as reclaimed land for other applications. It can also be employed to recover landfilled resources such as a soil fraction for reuse on-site as cover material and for use as a soil amendment. Based on the few analyses reported thus far, the heavy metal content and other characteristics of the recovered soil fraction indicate that the fraction can be suitable for landfill cover material. However, it should be emphasised that the characteristics of the recovered materials are substantially a function of the composition of the buried waste - including concentrations of heavy metals and of other toxic compounds. Some organic materials may be recovered that may have a use as a refuse-derived fuel. Low-quality ferrous scrap is readily recovered, but its utility has only been demonstrated to a limited degree. The percentage of recovered materials and their characteristics and properties are functions of the composition of the landfilled material and the configuration and operating conditions of the landfill mining process. The concept of landfill mining and reclamation and related technology merits serious consideration. It may be relevant to consider the incorporation of the concept into landfill design so that the landfilled waste can be readily accessible for mining.

References:

1. **CalRecovery, Inc. and Solid Waste Association of North America (SWANA),** *Evaluation of the Collier County, Florida Landfill Mining Demonstration,* prepared for the US EPA, Contract No. 850-0991-1, EPA/600/R-93/163, Cincinnati, Ohio, September 1993
   [return to text]
2. **Shuval, Hillel,** *Composting Municipal Garbage in Israel,* Tavruau, July-December 1958.
   [return to text]
3. *Personal communications,* 1960-70.
   [return to text]
4. **CalRecovery,** *Metro Manila Solid Waste Management Study,* (1982).
   [return to text]
5. **Morelli, J,** *Municipal Solid Waste Landfills: Optimization Integration, and Reclamation,* NYSERDA, Albany, NY
   [return to text]
6. **Naber, T,** *Mining the Landfill: The Ultimate Resource Recovery,* Waste Age, 196-197, November 1987
   [return to text]
7. **State of Florida Governor's Energy Office and the Board of Collier County Commissioners Solid Waste Management Dept,** *Feasibility Study: Landfill Mining at Collier County, Florida,* Naples, Florida, September 1987.

[return to text]

8. **Stessel, RL and Murphy, RJ**, *Processing Material Mined from Landfills*, Interim Report Vol II, University of South Florida, Tampa, Florida, September 1991.
[return to text]
9. **Watson, T**, *Recycling the Landfill: The mining of disposal sites,* Resource Recycling, 20,21,58,59, September/October 1988.
[return to text]
10. **Pohland, FG and Harper, SR**, *Critical Review and Summary of Leachate and Gas Production from Landfills - Draft Final Report*, US Environmental Protection Agency, 1984
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Pages prepared by Ecosaurus: chris@ecosaurus.co.uk