LANDFILL BIOREACTOR FINANCIAL ANALYSIS – MONTEREY PENINSULA LANDFILL, MARINA, CALIFORNIA

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ABSTRACT: The Monterey Peninsula Landfill, owned and operated by the Monterey Regional Waste Management District, is a municipal solid waste facility that is permitted under the State of California landfill regulations. In order to evaluate the potential cost benefits related to operating the site as a bioreactor, the District commissioned a consultant to determine the feasibility and benefits of changing their current operational procedures. The evaluation included a review of existing information and a detailed financial analysis and comparison between current practice and the operation of the site as a bioreactor. The results of the evaluation determined that the rapid degradation of refuse within a bioreactor will be beneficial for long-term health and safety, environmental protection, and methane gas generation.

Keywords: Bioreactor, Enhanced Methane Generation, Landfill, Financial Analysis

INTRODUCTION

The Monterey Peninsula Landfill (MPL) is a Class III sanitary landfill covering an area of approximately 126 hectares. The site is located in Northern Monterey County, California approximately 1.6 km east of State Highway 1 and 3.2 km north of the City of Marina. The MPL began accepting waste in 1966 and was constructed in a series of modules. The site currently receives approximately 209,000 metric tons of municipal solid waste per year delivered to the landfill by the general public and commercial haulers.

Disposal operations are currently focused in the Module 4 area, just to the east of the existing Materials Recovery Facility (MRF). Wastes are disposed of utilizing the area method of disposal, with waste lifts averaging 4.6 meters in thickness. Wastes are placed and compacted in thin layers on a working face sloped no steeper than 3:1 (horizontal:vertical). Soils for intermediate and working face cover, consisting generally of sands, are excavated from the upland plateau area south and east of the current landfill area. Sand has also been sold to local contractors for off site use.

The owner and operator of the MPL, the Monterey Regional Waste Management District (District), commissioned a consultant to conduct a financial cost-benefit analysis of their landfilling operation to determine the feasibility of operating the site as a bioreactor. A landfill that is operated as a bioreactor has many potential benefits. The more significant benefits include expedited methane generation and recovery, extension of landfill life due to enhanced refuse settlement, and improved leachate quality. The rapid degradation of the refuse within a bioreactor will be beneficial for long-term health and safety and environmental protection over the post-closure period of the landfill. The expedited methane generation will also provide the potential for additional beneficial uses of landfill gas.

The design and operation of a bioreactor landfill is different than the standard “dry tomb” landfill. For the design, the leachate collection system needs to be constructed to handle the increase in leachate generation due to liquid addition. The liner system itself may also require changes to ensure containment of the increased leachate quantities. The operational constraints involved with the liquid distribution system and landfill gas collection would also be considered in the cost benefit analysis. In order to provide the reader with a broad overview of landfill bioreactor technology, the authors have included a discussion on bioreactors in general, their benefits, and then present the financial analysis for the potential bioreactor at the MPL.

BIOREACTOR BACKGROUND INFORMATION

The information provided within this section is a summary of a “White Paper” presented at the Solid Waste Association of North America (SWANA) 5th Annual Landfill Symposium (Pacey, et al. 2000). A

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bioreactor landfill is a sanitary landfill that uses enhanced microbiological processes to transform and stabilize the readily and moderately decomposable organic waste constituents within 5 to 10 years of bioreactor process implementation. The bioreactor landfill significantly increases the extent of organic waste decomposition, conversion rates, and process effectiveness over what would otherwise occur within the dry tomb landfill. Stabilization means that the environmental performance measurement parameters (landfill gas composition and generation rate and leachate constituent concentrations) remain at steady levels, and should not increase in the event of any partial containment system failures beyond 5 to 10 years of bioreactor process implementation.

The bioreactor landfill requires certain specific management activities and operational modifications to enhance microbial decomposition processes. The single most important and cost-effective method is liquid addition and management. Other strategies, including waste shredding, pH adjustment, nutrient addition, waste pre-disposal and post-disposal conditioning, and temperature management, may also serve to optimize the bioreactor process. Successful implementation also requires the development and implementation of focused operational and development plans.

In effect, the bioreactor landfill is merely an extension of the accepted leachate re-circulation landfill option provided in the US Federal Landfill Regulations and adopted by the State of California. However, the bioreactor process requires significant liquid addition to reach and maintain optimal conditions. Leachate alone in some geographical areas such as the MPL may not be available in sufficient quantity to sustain the bioreactor process. Water or other non-toxic or non-hazardous liquids and semi-liquids are suitable amendments to supplement leachate (depending on climatic conditions and regulatory approval). Other process amendment strategies may also be included, subject to regulatory approval.

Shortly following closure of a bioreactor landfill, the landfill gas generation rate will usually be at its highest. It will then quickly decline over the next 5 to 10 years to a stable and relatively low and declining rate. Similarly, shortly after landfill closure, many leachate contaminant concentrations will change from levels regarded as highly polluted to much lower levels normally characteristic of extended stabilization. The leachate quantity at closure will be a finite amount, amenable to on-site treatment with limited need for off-site transfer, treatment, and disposal. In the event of post-closure partial containment system failure, the quality of the leachate generated from infiltration into a bioreactor landfill will be much better than other drier landfills.

Evidence suggests that bioreactor landfills can meet the prescribed regulatory requirements. A 1997 SWANA survey of 130 US bioreactor landfills indicates that most environmental and other relevant concerns have been resolved; information on leachate re-circulating landfills in existence worldwide is similarly positive.

Numerous benefits can be derived from a bioreactor landfill. These are situation-dependent and can affect different parties or stakeholders in different ways. They can accrue in the form of environmental, regulatory, monetary, and social benefits.

Some of the key benefits include 1) rapid settlement - volume reduced and stabilization within 5 to 10 years of bioreactor process implementation, 2) increased gas unit yield, total yield and flow rate – almost all of the rapid and moderately decomposable organic constituents will be degraded within 5 to 10 years of closure, and 3) improved leachate quality - stabilizes within 3 to 10 years after closure, and early land use possible following closure.

Key benefits for the maximizing of landfill gas capture for energy recovery projects include: 1) significant increase in total gas available for energy use which provides entrepreneurial opportunities, 2) potential increase in total landfill gas extraction efficiency (enabled over a shorter generation period), 3) increase in fossil fuel offsets due to increased gas energy sales 4) assistance in defraying landfill gas non-funded environmental costs, and 5) significant economy of scale advantage due to high generation rate over relatively short time.

Key benefits for increased landfill space capacity reuse do to rapid settlement during operational time period include: 1) increased landfill space capacity reuse due to rapid settlement during operational time period 2) increase in the amount of waste that can be placed into the permitted landfill airspace (effective density increase), 3) extension of landfill life through additional waste placement, 4) deferred capital and financing costs needed to locate, permit, and construct replacement landfill results in capital and interest savings, and 5) significant increase in realized waste disposal revenues.

Key benefits for improved leachate treatment and storage include: 1) low cost partial or complete treatment; significant biological and chemical transformation of both organic and inorganic constituents, although mostly relevant to the organic constituents, 2) reintroduction of all leachate over most of the operational and post-closure care period significantly reduces leachate disposal costs, and 3) absorption of leachate within landfill available up to field capacity.

Key benefits for reduction in post-closure care, maintenance and risk include: 1) reduction in post-closure care, maintenance and risk, rapid waste stabilization (within 5 to 10 years) minimizes environmental risk and liability due to leachate and gas, landfill operation and maintenance activities are considerably reduced, post-closure landfill monitoring activities can be reduced, and reduction of financial package requirement.

Another major benefit of bioreactors may come from greenhouse gas abatement. Bioreactors can generally rapidly complete methane generation while attaining maximum yield. This can be combined with nearly complete capture of generated gas using the bioreactor landfill in combination with a landfill gas to energy project. With this approach, the high generation level and gas capture efficiency maximizes landfill greenhouse gas offset potential.

FINANCIAL ANALYSIS

General

In recent years, the waste industry has begun to recognize airspace as a real commodity and has started to explore ways to preserve it and make the best use of capacity. The increase in revenue due to increased density of waste is fairly easy to quantify. Another benefit easily quantified is increased site life in which closure and post-closure accruals can be spread over longer periods of time. Our analysis did not take into account the accrual of closure and post-closure costs. Also, expansion of the landfill gas to energy plant located on the MPL site, to utilize the increased gas production due to the bioreactor process, can easily be quantified and accounted for in the proforma.

Bioreactors have become an avenue to enhance the economics and environmental protection of a waste facility. Much research and several laboratory studies have been performed to show the benefits of bioreactors and recently, financial impacts are starting to be evaluated.

For the financial analysis conducted for the MPL, an anaerobic bioreactor option was compared to the typical dry tomb landfill operations currently conducted at the site. The new cell anaerobic bioreactor would involve the addition of liquids to the waste mass by means of a HDPE piping system and bio-solids added to the working face as the cells are being filled. The addition of liquids to the waste mass has also been referred to as leachate re-circulation. On average, the Monterey area receives less than 0.5 meters of precipitation a year. This amount of precipitation will produce some leachate, but probably not enough to operate a bioreactor at full capacity. Therefore, additional liquid beyond that collected in the leachate collection system may be needed to enhance the full bioreactor process. The District has additional water available from a dewatering system located on site. From previous bioreactor studies, the moisture content of the waste has to approach 40% to 45% to provide enough moisture to enhance and keep the bioreactor processes functioning (Reinhardt and Ham, 1974).

Assumptions

The authors assumed that each bioreactor cell being constructed at the MPL would be on the order of 4 hectares. The total size of the permitted landfill footprint is assumed to be approximately 101 hectares. Total waste thickness was assumed to be on the order of 26 meters. The authors also assumed the site would operate 300 days per year. Total volume of the site was assumed to be just over 15 million cubic meters. Each 4-hectare cell would have a capacity on the order of 600 thousand cubic meters with one half of the cell consisting of floor area for leachate collection. Total incoming waste flow of 725 metric tons per day, an in-place density of 0.83 grams per cubic centimeter, and a gate rate of US $15.40 per metric ton were provided by the County. It should be noted that this exercise is a relative financial analysis.

The results of a literature search indicated that a 30 percent increase in the density of in-place waste (or in other words a 30 percent gain in airspace) for a properly operated bioreactor is very attainable (Reinhart and Townsend, 1997), (Harris and Schafer, 2002), and (Hater and Barbush, 2001). For conservatism, we assumed that over the life of a 4 hectare cell we would get a 20 percent increase in airspace.

According to Vogt and Augenstein (1999) and Pacey et al. (2000), gas production will increase substantially over standard Subtitle D cells. Hater and Barbush (2001) suggest at a minimum gas production will be 2 times that of normal production. The District provided gas generation data from the existing waste in-place. The authors used this data to calibrate the input parameters for the EPA Landfill Air Emissions Estimation Model to match existing conditions. Using the calibrated input parameters, the methane generation was estimated for future landfilling operations. For conservatism, the authors then used 1.5 times the normal production to estimate the incremental increase in methane gas production following bioreactor implementation.

In regard to the power production, assumptions used were from documented information provided by the District and typical experience with landfill gas-to-energy projects. Capital expenditures for expanding power production capabilities were estimated from the District's and typical experience. Costs will be incurred for increasing well field efficiency, power generation sets, and yearly operation and maintenance costs.

Bioreactor investment can be estimated by applying capital costs to the entire site and to each additional cell. Costs attributed to the entire site were spread over the initial 20 year life of the facility similar to the accrual process. Some costs that were included in the start up operation were a leachate storage tank, odor control, gas system upgrades, etc. The authors did not include replacement cost of equipment pumps, piping, etc. beyond the original design. We included the capital costs to permit, install, and operate the completed bioreactor as designed. We also included some yearly maintenance cost estimates from previous experience.

Costs were also estimated for the development of each 4-hectare bioreactor cell. The liquid distribution piping systems were assumed as follows: 1) vertical perforated pipe spacing was assumed to be every lift of waste or on the order of 4.5 meters on center, 2) horizontal perforated pipe spacing was assumed to be 15 meters on center, 3) conservatively, perforated pipes were assumed to be surrounded by .17 cubic meters of gravel per 30 cm of pipe. Many bioreactor sites use revenue-producing backfill around pipes such as tire chips or glass.

We also conservatively assumed a substantial upgrade in the leachate collection system. The upgraded system was assumed to have a cushion geotextile with 60 cm of high permeability granular material. Other options such as substituting tire chips for 30 cm of the drainage layer could be used to lower this capital expenditure. Since more flow into the leachate collection and recovery system will occur, we assumed that the LCRS pumps would need to be upgraded. Costs were also included for extra geomembrane to piggy back over some pre-existing areas of the MPL that did not have geomembrane liner systems.

Estimated bioreactor yearly operation and maintenance (O&M) costs included personnel, analytical, monitoring, and equipment costs. Those costs were estimated from a literature search and from our experience.

Results

Table 1 presents the results of the financial analysis. In our analysis, the total increase in revenue per year due to bioreactor activities is a direct result of the increase in airspace and the generation of power. The financial benefits provided are partially offset by an increase in investment required in the technology and science of bioreactors and the increase in operational costs for the bioreactor system and other resultant maintenance items (odor control and health/safety programs). Our analysis assumes 15 to 20 percent contingency on most capital, operation and maintenance costs.

There have been several benefits and risks excluded from this analysis because there is some uncertainty surrounding operation of the full-scale bioreactor. The potential benefits excluded are: reduced post-closure period, reduced heavy equipment, decreased air emissions, and deferral of cell construction and capping, since each constructed cell will have a longer individual life. The potential risks excluded are: change in construction costs for wider cells, allowing for flatter final grades, change in final slope grades resulting in loss of airspace (need flatter final grades for stability), and safety (wet working face, odors, fire and infectious waste).

CONCLUSION

The results of our analysis presented in Table 1 indicate a financial gain on the order of US 2 million dollars for implementation of a bioreactor system. Using what we believe are valid assumptions, the airspace recovery, increased density, and increase in landfill gas production can equate to a significant financial gain and longer life for the Monterey Peninsula Landfill.

TABLE 1 Revenue Increase with Bioreactor Option

Revenue / (Expense)	Years 1-20
Increase in Airspace	$3,950,802
Liquid Waste Revenue	$900,000
Power Production Revenue	1,870,282
Power Production Capital Costs	($160,127)
Power Production Maintenance & Operation Costs	($779,284)
Bioreactor Investment Costs (Entire Site Accrued Over 20 yrs)	($27,500)
Construction Costs – Module 4 (Cushion Geotextile and Gravel)	($910,271)
Design and Permitting Costs – Module 4	($100,000)
Yearly Bioreactor Operating, Piping, Maintenance, Costs, Etc.	($2,595,468)
Total Increase/Decrease in Revenue	**$2,125,934**

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