Evaluation of Methane Potential of Closed Landfills

Refuse disposal is an issue that must be addressed by every community in the U.S., as well as internationally. In 2009, 243 million tons of municipal solid waste (MSW) has been generated in the U.S., with a per capita generation rate of 4.34 lb/day which is significantly higher than 2.68 lb/day in 1960. Of the total waste generation, approximately 54.3% was buried in landfills. While portions of this waste are recycled and composted (33.8%), and converted to energy (11.9%), landfills will remain a significant aspect of MSW management for the foreseeable future.

Landfills:

Sanitary landfilling in the United States has made monumental strides in the last 30 years, moving from open dumps with little or no control to state-of-the-art controlled facilities with sophisticated containment systems, environmental monitoring, improved operational practices, and increased regulation. Since the implementation of the Resource Conservation and Recovery Act of 1976, municipal solid waste (MSW) landfills have been engineered, built and operated as dry tombs to minimize the generation and spread of hazardous leachate from the degradation of the waste. This management technique uses the landfill space as a safe storage facility. Minimum amount of moisture is allowed to enter and retain in the landfill. The absence of moisture in the waste prolongs the decomposition which can take as much as 50 to 100 years for complete decomposition. Conventional dry-tomb MSW landfills may occupy an area ranging from several acres to hundreds of acres (Figure 1). Due to rapid growth and urbanization, requirement for new locations for landfilling of
MSW kept increasing but finding a suitable location has become a predominant problem. Therefore, waste minimization and increasing the capacity of landfills within the same area is becoming a major consideration for the state agencies and federal regulatory bodies. Consequently, there have been substantial changes in the design and operation of landfills over the past few decades. A bioreactor landfill is operated to enhance refuse decomposition, gas production, and waste stabilization. A major aspect of bioreactor operation is the addition of liquid and recirculation of collected leachate back through the refuse mass to enhance waste decomposition and rate of gas production.

**Refuse Degradation and Landfill Gas Generation:**

Landfills can serve not only as waste repositories but also as significant sources of renewable energy, which can help reduce dependence on foreign petroleum. As microbes degrade the organic fraction of waste, methane (CH\(_4\)) is generated, along with carbon dioxide (CO\(_2\)), water, and other trace landfill gas (LFG) constituents. Typically landfill gas is the product of methane fermentation stage (fourth stage) of a five stage life cycle of altering aerobic and anaerobic activity that takes place in a landfill (Figure 2). This stage lasts the longest, often lasting as long as or longer than all the other phases combined and constituting the bulk of the landfill’s operational lifetime and post-closure care period.

Subtitle D regulations mandate the installation of LFG vents, collecting and flaring (Figure 3) LFG from landfills irrespective of whether this gas is used for any beneficial purpose or not. Methane, the primary constituent of natural gas, if not flared, can be put to beneficial use. Depending on the quality and quantity, it can be used for heating, to generate electricity, hence replace fossil fuels in industrial and manufacturing operations, or can be upgraded to pipeline-quality gas where the gas may be used directly or processed into an alternative vehicle fuel. Using LFG also helps to reduce odors associated with LFG emissions, and can improve safety by reducing explosion hazards from gas accumulation in structures on or near the landfill.
Comprising 40-60% of landfill gas by volume, methane is not only potentially an energy source, but also a potent greenhouse gas. Capturing and burning methane for energy is thus important, not only as a measure for reducing fossil fuel dependence, but also as a measure for reducing the potency of greenhouse gas emissions.

**Closed Landfills:**

Whatever may be the current practice for new landfills, the old closed landfills still remain occupying large tracts of land (Figure 1). At present, there are more than 40 closed MSW landfills around DFW area of North Texas. Due to their conventional dry-tomb design, most of them are still in their methane generation phase (Figure 4) of degradation and far from being stabilized. This often becomes a major constraint against redevelopment on these closed sites. Though the rate of landfill gas production may be significantly lower than that of bioreactor landfills, the landfill gas containing methane is still produced. If not collected and combusted, over time, this landfill gas is released to the atmosphere. In the United States, landfills are one of the largest sources of anthropogenic emissions of methane, accounting for 23 percent of total methane emissions. Due to their emission potential, most of the landfills are required by law to vent and flare the generated gas for several decades even after closure. This post closure monitoring and maintenance is expensive and makes these closed landfills a huge liability. This gas, which needs to be collected and flared, if put to beneficial use, could turn the liability into a source of revenue.

**Power Generation from Closed Landfill:**

Predicting how much gas will be generated by a given waste mass over a set period of time is more art than science. Given typical assumptions concerning the characteristics of the deposited waste, the average rate of landfill gas production is approximately 300 scfm for every million tons of waste in place. Assuming 50% of produced landfill gas as methane this is equivalent to 9108000 BTU/hr, which is capable of producing 778 kW of energy. A 10 acre landfill with 50 ft waste depth with moderate compaction has approximately 405000 ton of waste in place.

**Challenges:** Closed landfills, much like small landfills, have the limitation of having inadequate flow (scfm) of LFG for a sustaining a profitable landfill gas to energy project using traditional generators. Because most LFG-rated generator sets require more than 350 scfm LFG for full power production. When operated at less than full capacity usually the operating cost becomes more than the revenue for the conversion project to be profitable.

**Solution:** This can be overcome by simply using microturbines instead of traditional LFG-rated internal combustion engines.
Microturbines are a new type of combustion turbine that can be used in stationary power generation applications. Commercially available microturbines are typically about the size of a refrigerator and can generate electricity in the range of 25 to 500 kilowatts (kW). The commercial application of microturbines for landfill gas recovery began in early 2001. By the summer of 2003, it has been estimated that there were about 100 microturbines operating on landfill gas in the U.S. and around the world. Figure 5 presents microturbines in operation at a landfill site.

**Pre-Subtitle D Closed Cell at City of Denton Landfill:**

Waste filling at the closed cell at the City of Denton Landfill of Texas started in 1985. The cell was closed at around 1990. At present the waste inside the landfill is approximately 20 to 25 years old. This cell has a footprint of approximately 30 acres and around 30 gas collection wells are in operation there. To evaluate gas potential of a closed landfill, it is important to have a thorough understanding of the characteristics of the in situ waste. In October 2010, 12 landfilled MSW samples were collected from different depths of two 60 ft long boreholes. Due to the conventional operation practice, most of the samples were found to be un-degraded and almost like fresh waste. The volatile solids content of these samples varied between 42% to 85% with an average of 70%. This clearly indicates that the waste still has a high potential for methane generation left.

**Summary:**

At present, there are approximately 4200 closed and abandoned MSW Landfills throughout the state of Texas. A closed landfill might have potential benefits for gas recovery and utilization due to the presence of organic contents in the MSW. As decomposition process usually continues for 50 to 100 years for conventional landfills, many of these landfills are still in their methane fermentation phase. These are potential energy sources waiting to be utilized. In the closed traditional landfills, gas generation rate may be slow. In that case microturbines may be used for conversion of landfill gas to electricity. In case the generated electricity is not enough to be supplied to the power grid, it can still be used for operation and maintenance of the landfill site itself. It can make the landfill self sufficient and convert the liability into a source of revenue.

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