FIGURE 1 Minitube blanket installation

Case Study

A minitube blanket for landfill gas collection and containment

By Stephan Fourmont, Pascal Saunier and Toraj Ghofrani

Landfill gas (LFG) is produced during the decomposition of putrescible material in landfills. Often referred to as biogas, LFG is a source of odors and fugitive greenhouse gas (GHG) emissions. LFG is typically 40%–60% methane, which is 25 times more potent to affect climate change than carbon dioxide (U.S. Environmental Protection Agency 2013). LFG must be removed from the landfill to reduce or eliminate odors, to limit the migration of methane to the atmosphere and to comply with regulatory requirements.

The management of LFG at landfills is an important, and often costly, operational aspect of a well-run landfill. The need to install a gas collection and control system (GCCS) is dependent on the amount and type of waste accepted. Typically, LFG is controlled by an active vacuum blower system, which extracts LFG through a network of horizontal collectors embedded in rock-filled trenches inside the waste. The collected LFG is typically sent to a destruction device, such as a flare, where it is combusted, and the methane is converted to carbon dioxide. Because of the energy potential of the methane gas, landfill gas-to-energy (LFGTE) projects have been developed to capitalize on renewable sources of green fuel. In general, LFGTE projects use the LFG to fuel specially designed turbines, reciprocating engines or boilers. LFGTE projects can have design lives in excess of 20 years and range in size from a few kilowatts to 10 megawatts or more. Also, LFG can be processed into a compressed or natural gas for home heating or vehicle use, respectively.

The success of an LFGTE project is directly related to the performance of the GCCS. Traditional methods of LFG collection can be time-consuming and expensive to install, and installation sometimes can be delayed due to seasonal and budgetary issues. This paper presents the significant advantages of using a tubular drainage geocomposite for LFG collection as compared with traditional horizontal LFG collectors (**Figure 1**).

PROJECT HIGHLIGHTS

CEDAR HILLS REGIONAL LANDFILL

OWNER
King County Solid Waste Division

LOCATION
Maple Valley, Wash.

GENERAL CONTRACTOR
King County Solid Waste Division (in-house)

DESIGN ENGINEER
Toraj Ghofrani, P.E.

GEOSYNTHETIC PRODUCT
DRAINTUBE 500P LFG4 D25

GEOSYNTHETIC MANUFACTURER
AFITEX-Texel

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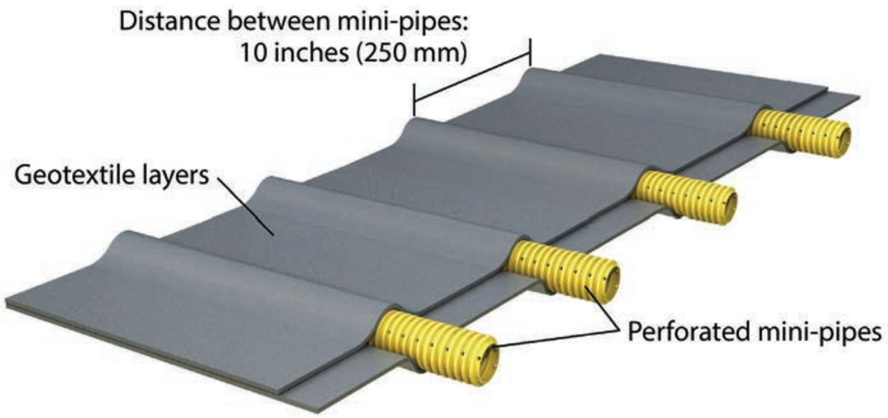

FIGURE 2 Minitube blanket description

FIGURE 3 Connection of the minitube blanket to the collector pipe

Minitube blanket description and installation

As this technology differs from more common solutions, it is important to first describe the product to be used. The minitube blanket is comprised of 1-inch (25-mm) corrugated polypropylene perforated pipes spaced on 10-inch (250-mm) centers between two nonwoven geotextile layers (**Figure 2**).

Tubular drainage geocomposites have been used in landfill applications around the world for more than 25 years. They are compliant with ASTM D7931, Standard Guide for Specifying Drainage Geocomposites, and are defined as multilinear drainage geocomposites in ASTM D4439, Standard Terminology for Geosynthetics.

An important characteristic of tubular drainage geocomposites is that they maintain their transmissivity under significant normal stresses (Saunier et al. 2010) because they don't experience geotextile intrusion into the drainage conduits (the minitubes) and no creep in compression of the minitubes when confined. Therefore, for most applications, the applied combined reduction factors for tubular drainage geocomposites are almost half of those applied to standard geonet geocomposites (Maier and Fourmont 2013).

A roll is typically 13-feet (4-m) wide and it replaces a 3-foot (0.9-m) wide × 6.5-foot (2-m) deep trench filled with aggregates surrounding a 6-inch (150-mm) diameter perforated high-density polyethylene (HDPE) pipe. Common spacing between horizontal LFG collectors is about 50–100 feet (15–30 m) horizontally and 30–40 feet (9–12 m) vertically. This is a significant loss of airspace and waste disposal tipping fees during the lifetime of a landfill.

The minitube blanket is unrolled directly on the waste and connected to a collector pipe using connectors specially developed to fasten the pipes from the composite to the collector pipe (**Figure 3**). Due to its limited thickness and its low hydraulic conductivity in contrast with the surrounding waste, the minitube blanket network won't obstruct the downward leachate flow into the waste mass and reduce the potential for plugging the perforated LFG collectors. Nevertheless, some specific measures will be taken to manage the condensates (gradation of the support with a slope away from the manifold, condensate drain at one end of the manifold, etc.).

Waste is placed directly over the minitube blanket (**Figure 4**). A minimum of 3 feet (0.9 m) of selected waste should be placed on top of the geocomposite prior to operating a compactor over the area.

FIGURE 4 Backfilling with waste

The size and weight of the waste compactor, as well as the length of the compactor teeth, should be considered when designing the thickness of the initial waste layer over the geocomposite.

In-place behavior

For horizontal LFG collection, the flow and the head loss in the minitube blanket are governed by the minitubes (the head loss in the geotextile layers being negligible). In a first stage, the low-pressure Muller equation can then be used because the pipes of the geocomposite follow the same physical laws as a conveyance pipe for gas collection (Steinhauser and Fourmont 2015).

The gas flow of the minitube is given from its water flow using **Equation 1** (Faure and Auvin 1995):

$$\frac{Q_g}{Q_w} = \frac{(q_p)_g \times i_g}{(q_p)_w \times i_w} = \frac{\alpha(i_g)^{n+1}}{\alpha(i_w)^{n+1}} = (\frac{\rho_w}{\rho_g})^{n+1} \quad (1)$$

With:
Q: flow drained by the minitube
(Q_w: water flow, Q_g: gas flow)
q_p: discharge capacity of the minitube [$(q_p)_w$ for water, $(q_p)_g$ for gas]
i: hydraulic gradient
(i_w for water, i_g for air)
α, n: constants
ρ: density (ρ_w for water, ρ_g for gas)

Compared to water, this ratio is about 28 for air, 22 for CO_2 and 37 for CH_4.

From Faure and Matichard (1993), the maximum waterhead in the minitube function of the collected flow per unit area is given by **Equation 2**:

$$\Delta h = \frac{n+1}{n+2} \times \left(\frac{d \times F}{\alpha}\right)^{(1/n+1)} \times L^{(n+2)/(n+1)} \quad (2)$$

With:
Δh: waterhead (water column)
d: distance between the minitubes
F: flow of liquid collected per unit area

The flow drained by the minitube blanket is also given by **Equation 3**:

$$Q_w = F \times L \times d \quad (3)$$

Then, using **Equation 1** and **Equation 3** in **Equation 2**, the head loss in the minitube is given by **Equation 4**:

$$\Delta P = \frac{n+1}{n+2} \times \frac{\rho_w}{\rho_g} \times \left(\frac{Q_g}{\alpha}\right)^{(1/n+1)} \times L \quad (4)$$

Lymphea software combines these equations to determine the flow of gas collected by the geocomposite as a function of the horizontal LFG collector length and the applied vacuum. This software has been developed by the Laboratoire Interdisciplinaire de Recherche Impliquant la Géologie et la Mécanique (LIRIGM) from the University of Grenoble, France, and validated by large-scale tests. It can be obtained from the manufacturer.

A vacuum loss was higher in the traditional LFG collector as compared with the minitube blanket (65% versus 58%), indicating a better distribution of vacuum along the trench by the minitube.

Comparison to a traditional trench

The performance of a minitube blanket and a traditional horizontal LFG collector were tested side by side in the same 800-foot (245-m) refuse trench at Cedar Hills Regional Landfill, located in Maple Valley, Wash. (Ghofrani 2016). The traditional LFG collector was comprised of a 6-inch (150-mm) HDPE pipe with six 0.5-inch (13-mm) perforations, 60° apart and 6 inches (150 mm) on center. The geocomposite was comprised of 1-inch (25-mm) diameter corrugated polypropylene perforated minitubes needlepunched between two nonwoven geotextile fabrics. The tested geocomposite was 3-feet (0.9-m) wide with four minitubes.

The performance of a minitube blanket and of a traditional LFG collector were evaluated based on monitoring of the vacuum zone of influence, landfill gas flow rate, methane (CH_4), oxygen (O_2), nitrogen (N_2) and carbon dioxide (CO_2) data, using a GM 5000 field instrument. The vacuum measurements were made using a Magnehelic gauge at 50-foot (15-m) intervals along the length of the trench.

As presented in **Figure 5**, the vacuum along the trench decreased from 4.5–2.9 inches (114 to 74 mm) of water column (WC) in the traditional LFG collector as compared to 1.5–0.88 inches (38 to 22 mm) of WC in the minitube blanket. Therefore, a vacuum loss was higher in the traditional LFG collector as compared with the minitube blanket (65% versus 58%), indicating a better distribution of vacuum along the trench by the minitube.

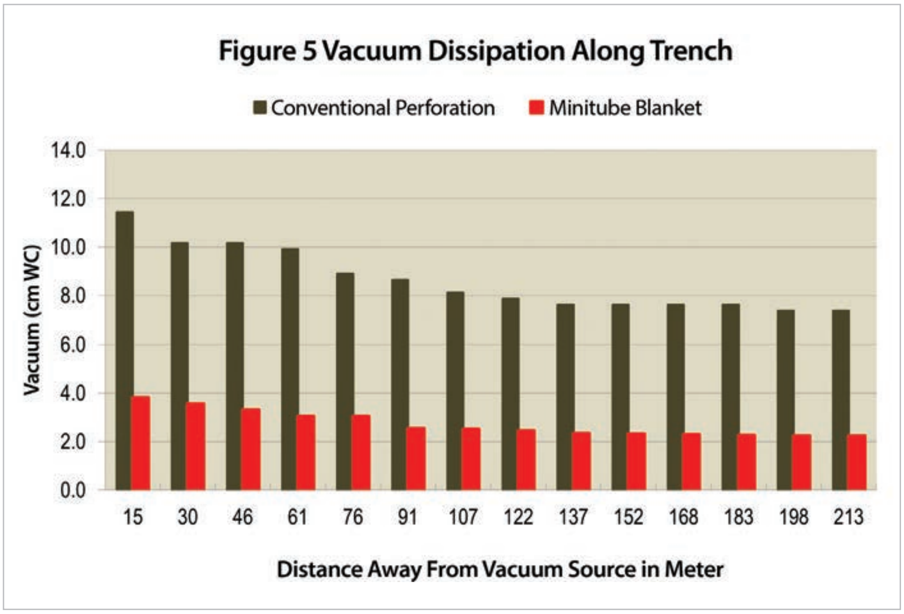

FIGURE 5 Vacuum dissipation along trench

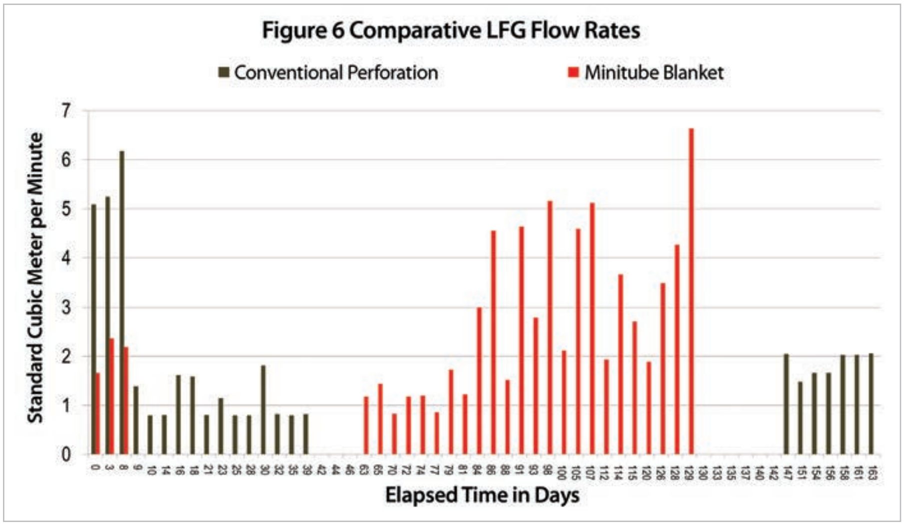

FIGURE 6 Comparative LFG flow rate

Moreover, due to numerous redundancies of corrugated polypropylene perforated pipes 10 inches (254 mm) apart, the minitube blanket offers a more reliable radius of influence to collect LFG than traditional LFG collectors 50–100 feet (15–30 m) apart.

Furthermore, even though the traditional LFG collector had higher vacuum availability, the minitube blanket provided equal if not better flow rates. As presented in **Figure 6**, the average LFG flow rate for the traditional collector was 67 standard cubic feet per minute (2 standard m^3/min), while the average LFG flow rate for the minitube blanket

	Quantity	Unit	KG CO_2 eq./lm
Excavation Work			
Waste density	1.5	tons/m^3	
Trench height	0.5	meters	
Soil extraction for 1 lm	3	tons	
Soil extraction using machinery			
lm of trench per day	200	lm/day	
Tons of soil extracted per hour	85.7	tons	
Fuel consumption per hour	40	liters	
Fuel consumption for 1 lm	1.4	liters	**4.12**
Soil extraction/application			
Labor costs per hour	30	dollars	
Number of workers	2		
Dollars for services for 1 lm	3.15	dollars	**0.12**
Minitube blanket			
Name of product	DRAINTUBE 500P LFG4		
Weight per lm	3.39	kgs	**11.33**
Transport to the site			
Distance to worksite	2000	kms one-way	
Transport of products	6.77	tons.kms	**1.74**
Application of the product on-site using machinery			
lm applied in 1 hour	75	lm	
Fuel consumption per hour	20	liters	
Fuel consumption per lm	0.27	liters	**0.79**
Product application (labor)			
Labor costs per hour	30	dollars	
Number of workers	3		
Dollars for services for 1 lm	1.2	dollars	**0.04**
		TOTAL	**18.14**

TABLE 1 Kg CO_2 eq. emissions per linear meter for the minitube blanket

was 97 standard cubic feet per minute (3 standard m^3/min) under the same condition and during the same testing period.

The minitube blanket performance was equally compatible with the traditional LFG collector with respect to fixed gases:

- The CH_4 concentrations ranged from 25%–58% for the traditional LFG collector and 33%–63% for the minitube blanket LFG collector.
- The O_2 concentrations ranged from 0.3%–1.3% and 0.0%–3.5%, while the N_2 concentrations ranged from 0.0%–46% and 0.0%–37% for the traditional LFG collector and minitube blanket, respectively.
- The CO_2 concentrations were similar for both the traditional LFG collector and the minitube blanket, ranging from 26%–30% and 26%–41%, respectively.

The rate at which microbes generate LFG can be best described as a slow diffusive process rather than a fast advective process. If an LFG collection system is designed with excessive vacuum pull/flow rates, excessive air intrusion may occur.

With almost half of the perforation area of the traditional LFG collector, the minitube blanket performance is similar if not better that the traditional LFG collector. Additionally, the geocomposite offers savings in airspace utilization due to its compact geometry. The corrugated polypropylene also offers more resiliency toward long-term landfill settlement.

Greenhouse gas emissions

The use of the minitube blanket in replacement of granular material permits the reduction of GHG emissions up to 87% equivalent CO_{2e} with m hydraulic performances (Durkheim and Fourmont 2010).

In the specific case of horizontal LFG collection, **Table 1** presents the CO_{2e} emissions per linear meter for the

	Quantity	Unit	KG CO_2 eq./lm
Excavation Work			
Soil density	1.5	tons/m³	
Trench height	2	meters	
Trench width	0.9	meters	
Soil extraction for 1 lm	2.7	tons	
Soil extraction using machinery			
lm of trench per day	70	lm/day	
Tons of soil extracted per hour	27	tons	
Fuel consumption per hour	40	liters	
Fuel consumption for 1 lm	4	liters	**11.77**
Soil extraction/application			
Labor costs per hour	30	dollars	
Number of workers	2		
Dollars for services for 1 lm	6	dollars	**0.22**
Quarry Gravel			
Gravel density	1.8	tons/m³	
Trench height	2	meters	
Trench width	0.9	meters	
Tons of gravel extracted for 1 lm	3.2	tons	**32.4**
Transport of gravel			
Distance from quarry to worksite	15	kms one-way	
Number of kms for 1 lm	2.43	kms	**2.62**
Application of gravel using site machinery			
Tons of gravel applied per hour	13.5	tons	
Fuel consumption per hour	40	liters	
Fuel consumption per lm	9.6	liters	**28.25**
Application of gravel			
Labor costs per hour	30	dollars	
Number of workers	2		
Dollars for services for 1 lm	14.4	dollars	**0.53**
Collector Pipe			
Diameter	150	mm	
Weight per lm	1413	tons/km	**3.37**
Transport from manufacturer to worksite			
Distance to worksite	50	kms	
Transport of products	0.07	tons/km	**0.02**
Product application (labor)			
lm of pipe installed per hour	10	lm	
Labor costs per hour	30	dollars	
Dollars for services for 1 lm	3	dollars	**0.11**
		TOTAL	**79.29**

TABLE 2 Kg CO_2 eq. emissions per linear meter for a 3-foot × 6.5-foot (0.9-m × 2-m) horizontal trench

minitube blanket considering a distance from the manufacturer to the landfill site of 1,240 miles (2,000 km).

In comparison, the calculation of CO_2 emissions per linear meter for a 3-foot (0.9-m) wide × 6.5-foot (2-m) deep trench filled with aggregates surrounding a 6-inch (150-mm) diameter perforated HDPE pipe is presented in **Table 2**.

The calculations were carried out using the carbon footprint method developed by the Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME). The use of the minitube blanket offers a considerable reduction of CO_{2e} emissions of 77% for the same or better performance. It represents a savings greater than 18 kg CO_{2e} per linear foot (more than 60 kg CO_{2e} per linear m) of horizontal LFG collector.

Conclusion

LFG collection has never been of greater concern than now in the waste management industry. Being able to efficiently collect landfill gas will help landfill owners-operators and municipalities increase their revenue by recycling methane and will reduce the negative impacts to the environment, like odors and fugitive GHG emissions. Trenches, gravel, pipes and geotextiles were used for decades to maximize the LFG collection efficiency. Solutions now exist to largely improve the management of LFG and convert it to renewable energy, as a natural and free resource.

One of the better emerging solutions is the minitube blanket technology, which offers a more flexible solution with an enhanced control over LFG collection, containment and conveyance, as well as a reliable vacuum radius of influence and comforting redundancy while drastically reducing construction costs, odor and fugitive GHG emissions. Lastly, one of the greatest advantages of the minitube blanket over a traditional LFG collector is saving landfill airspace for its intended refuse disposal and its corresponding revenue from tipping fees.

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