Use of a Minitube Blanket for Horizontal Landfill Gas Collection and Control

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Abstract

Landfill gas (LFG) needs to be efficiently and effectively extracted from active and closed landfills to comply with air quality regulations as well as to fuel beneficial uses. LFG extraction is performed by applying a vacuum onto vertical wells or horizontal collection trenches. LFG collection trenches are commonly constructed by excavating into the waste mass and backfilling the trench with aggregate and a perforated high-density polyethylene (HDPE) pipe. While LFG collection trenches are an important component to a well-operated landfill, the costs associated with constructing trenches and relocating waste are significant. This paper presents a review of tubular drainage geocomposite used for more than 5 years in replacement of traditional pipes and aggregates LFG trenches. The use of this geocomposite improves the zone of influence (ZOI) of the "trench" without reducing the collected flow, as well as reduces dramatically the costs and the Greenhouse gas (GHG) emissions.

INTRODUCTION

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 greenhouse gases. LFG is typically 40 to 60 percent methane which is a greenhouse gas that has 25 times more of an impact on climate change than carbon dioxide (USEPA 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 gas system which extracts LFG by applying a vacuum to a network of collection wells and trenches into the waste. In an active system, LFG is collected and 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 the "man-made" "green" fuel source. 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 gas for vehicle use.

The success of a 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 budget issues. This paper presents a review of the use of tubular drainage geocomposite (minitube blanket) for horizontal LFG collection into the waste mass during landfill operation.

MINITUBE BLANQUET DESCRIPTION AND INSTALLATION

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

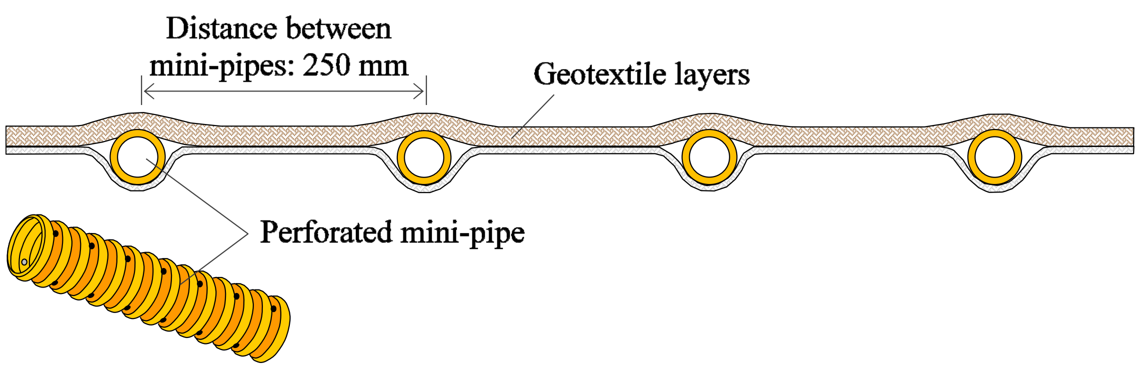

Figure 1: Minitube blanket description.

Tubular drainage geocomposites have been used in landfill applications over the world for 25 years. 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 primary high-flow component. Therefore, for most of the applications, the applied combined reduction factors for tubular drainage geocomposite are almost half of those applied to standard geonet geocomposites (Maier and Fourmont, 2013).

A roll is typically 4 m (13-ft) wide and it replaces a 0.9 m (3-ft) wide by 2 m (6.5-ft) deep trench filled with aggregates surrounding a 150 mm (6-inch) diameter perforated HDPE pipe. Common spacing between horizontal LFG collectors is about 15 to 30 m (50 to 100-ft) horizontally and 9 to 12 m (30 to 40-ft) vertically.

The minitube blanket is unrolled directly on the waste (Figure 2) and connected to a collector pipe using connectors specially developed to fasten the pipes from the composite to the collector pipe (Figure 3).

Figure 2: Minitube blanket installation.

Figure 3: Connection of the minitube blanket to the collector pipe.

Due its limited thickness and its low hydraulic conductivity contrast with the surrounding waste, the minitube blanket network won't modify the leachate flow into the waste mass and won't concentrate it as a large trench network would. 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 are directly placed over the minitube blanket (Figure 4). A minimum of 1 m (3-ft) of selected waste, should be placed on top of the geocomposite prior to operating a compactor over the area. 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 minitube blanket.

Figure 4: Backfilling with waste.

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):

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

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 et al, 1993, the maximum water head in the minitube function of the collected flow per unit area is given by equation 2:

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

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

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

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

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

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

COMPARISON TO A TRADITIONAL TRENCH

Between September 2015 and March 2016, the performance of minitube blanket and traditional horizontal LFG collector were tested side by side in the same 245 m (800-ft) refuse trench at Cedar Hills Regional Landfill, located in Maple Valley, Washington (Ghofrani 2016). The traditional LFG collector was comprised of a 150 mm (6-inch) HDPE pipe with six 13 mm (1/2-inch) perforations, 60° apart, and 150 mm (6-inch) on center. The minitube blanket comprised of

25 mm (1-inch) diameter corrugated polypropylene pipe with two 1 mm (0.04 inches) perforations per valley, 180° apart, rotated 90°, and needle punched between two non-woven geotextile fabrics. The minitube blanket was 1 m (3-ft) wide with 4 pipes.

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

As presented in Figure 5, the vacuum along the trench decreased from 11.4 to 7.4 cm of Water Column [WC] (4.5 to 2.9 inches of WC) in the traditional LFG collector as compared to 3.8 to 2.2 cm of WC (1.5 to 0.88 inches of WC) in the minitube blanket. Therefore, a vacuum loss was higher in the traditional collector as compared with the minitube blanket (65% versus 58%), indicating a better distribution of vacuum along the trench by the minitube.

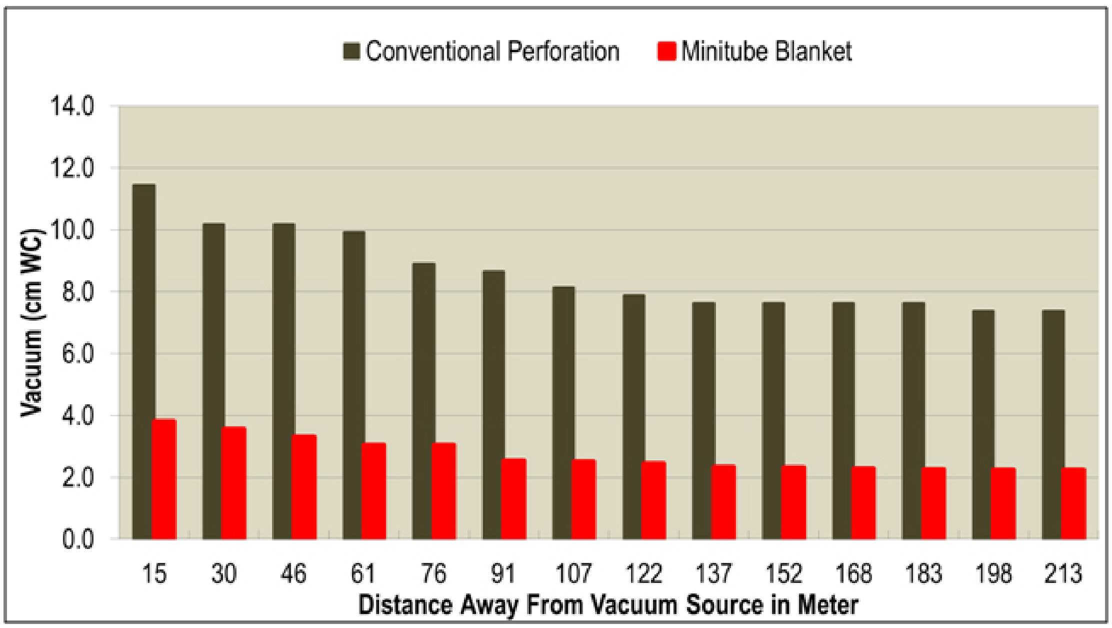

Figure 5: Vacuum dissipation along trench.

Furthermore, even though the traditional collector had higher vacuum availability (Figure 5), minitube blanket provided equal if not better flow rates. As presented in Figure 6, the average LFG flow rate for the traditional collector was 2 standard cubic meter per minute (m^3/min) (67 standard ft^3/min), while the average the average LFG flow rate for the minitube blanket was 3 standard m^3/min (97 ft^3/min) during the same testing period.

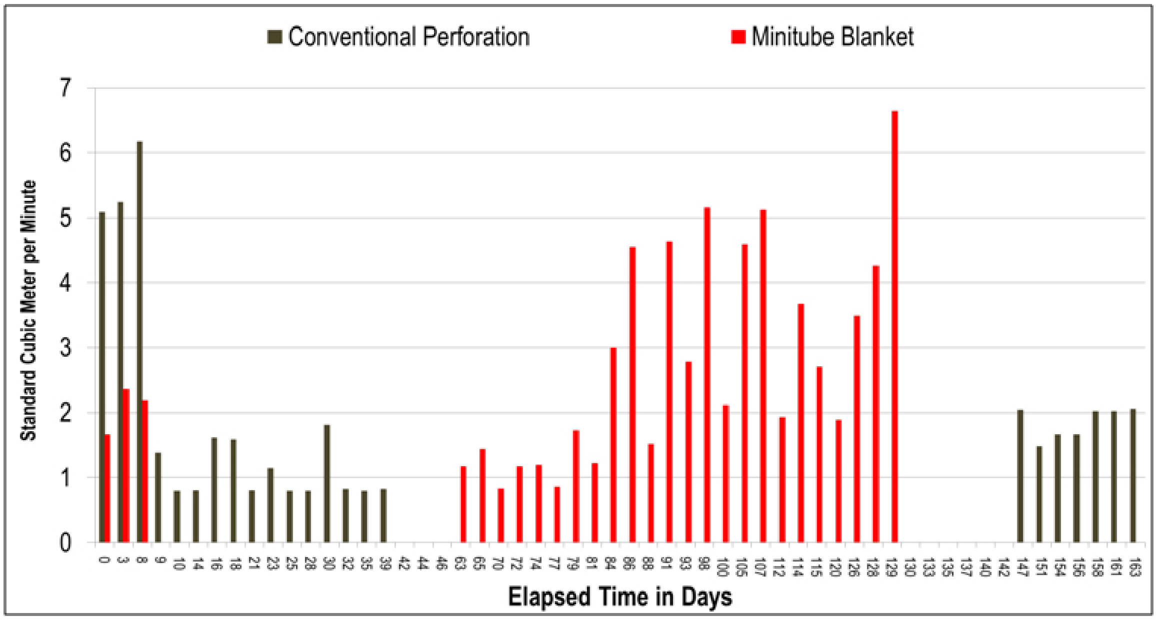

Figure 6: Comparative LFG flow rate.

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

- The CH4 concentrations ranged from 25% to 58% for the traditional LFG collector LFG collectors and 33% to 63% for the minitube blanket LFG collector.
- The O2 concentrations ranged from 0.3% to 1.3% and 0.0% to 3.5% while the N2 concentrations ranged from 0.0% to 46% and 0.0% to 37% for the traditional LFG collector and minitube blanket, respectively.
- The CO2 concentrations were similar for both traditional LFG collector and the minitube blanket, ranging from 26% to 30% and 26% to 41%, respectively.

The rate at which microbes generate LFG can be best described as slow diffusive process rather than fast advective process. If a LFG collection system is designed with excessive flow rates an air intrusion may occur. Conversely, any increased number of redundant horizontal and vertical collectors reduces air space utilization for refuse disposal.

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, minitube blanket offers savings in air space utilization due to its compact geometry. It also offers numerous redundancies due to its frequent and widespread use of corrugated polypropylene pipes which could offer a more resiliency towards long term landfill settlement.

GREENHOUSE GAS EMISSIONS

The use of minitube blanket in replacement of granular material permits to reduce GHG emissions up to 87% eq. CO_2 with equivalent hydraulic performances (Durkheim and Fourmont, 2010).

In the specific case of horizontal LFG collection, table 1 presents the equivalent CO_2 emissions per linear meter for the minitube blanket considering a distance from the manufacturer to the landfill site of 2000 km (1240 miles).

Table 1 kg CO_2 eq. emissions per linear meter for the minitube blanket.

	quantity	unit	Kg CO_2 eq./lm
EXCAVATION WORK			
Waste density	1.5	tons/m3	
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			
Labour 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 (labour)			
Labour costs per hour	30	dollars	
Number of workers	3		
Dollars for services per lm	1.2	dollars	**0.04**
		TOTAL	**18.14**

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

Table 2 kg CO_2 eq. emissions per linear meter for a 0.9 m x 2 m horizontal trench.

	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			
Labour 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	**32.40**
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 for 1 lm	9.6	liters	**28.25**
Application of gravel			
Labour 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	1.413	kg	**3.37**
Transport from manufacturer to worksite			
Distance to worksite	50	kms	
Transport of products	0,070	Tons/km	**0.02**
Product application (labour)			
lm of pipe installed per hour	10	lm	
Labour costs per hour	30	dollars	
Dollars for services per lm	3	dollars	**0.11**
		TOTAL	**79.29**

The calculations were carried out using the “carbon footprint” method developed by ADEME. The use of the minitube blanket offers a considerable reduction of CO_2 emissions of 77% for the same or better performance. It represents a saving greater than 60 kg CO_2 eq. per linear meter (more than 18 kg CO_2 eq. per linear foot) of horizontal LFG collector.

CONCLUSION

LFG collection has never been such a tremendous concern than nowadays in the waste management industry. Being able to efficiently collect landfill gas will help landfill owners-operators and municipalities to increase their revenue by recycling the methane and to reduce the negative impacts like odors and greenhouse gas generation. Trenches, gravel, pipes and geotextiles were used since decades to maximize the collection efficiency. Solutions now do exist to largely improve the management of LFG as a “natural and free” resource. One of them is the minitube blanket technology which offers a more flexible solution with an enhanced and controlled flow capacity, an adapted vacuum efficiency, an important redundancy while drastically reducing costs and GHG emissions during construction as well as avoiding air space lost occurred while trenching into the waste.

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