Geosynthetics Conference
Feb. 10-13, 2019 | Houston, TX USA

# Protection of Building Against Soil Gas Infiltrations Using Drainage Geocomposites

**Stephan Fourmont[1] and Jean-François Belanger, P.E.[2]**

[1]Afitex-Texel, 1300, 2e Rue, Parc Industriel, Sainte-Marie (QC) Canada G6E 1G8; sfourmont@draintube.net
[2]Alphard, 5570, Avenue Casgrain, bureau 101, Montreal (QC) Canada H2T 1X9; jfbelanger@alphard.com

## ABSTRACT

Construction of buildings on natural or degraded layers with the potential to generate gasses (biogas from waste, gas emission from polluted soils, radon, etc.) requires the installation of a gas collection and evacuation system to protect the health of the building's inhabitants. Replacing crushed stone drainage layers using perforated collector pipers with a multi-linear drainage geocomposite composed of non-woven geotextile layers, needle-punched together with perforated and corrugated polypropylene pipes regularly spaced inside, typically every 1 m (40 in.), allows for the collection of gasses across the covered surface and significantly reduces excavation work and worksite traffic. As part of an active or passive subslab depressurization system, multi-linear drainage geocomposites reduce vacuum dissipations. A specific set of connectors is available to optimize the connections between the geocomposite layer and the collection pipes.

## INTRODUCTION

The reclamation of industrial brownfield sites or former waste deposit sites for new developments is already common practice in various parts of the world. The infiltration of underground gases poses a serious threat to the safety of the occupants of these reclaimed sites. Gases generated by both waste products (biogas) and contaminated soils (such as Volatile Organic Compounds VOC), and even natural gases like radon produced by the natural decay of uranium, are commonly detected in affected areas. Subslab gas collection systems, using a natural permeable layer such as crushed stones paired with draining pipes and vents, are frequently used to prevent gas infiltration into new developments. However, geosynthetic products such as drainage geocomposites present an excellent alternative for both passive and active subslab gas collection systems. This technical paper aims to present a comprehensive overview of the design and installation of such systems, while demonstrating their benefits over conventional approaches to underground gas collection.

## UNDERGROUND GASES

Underground cases that can infiltrate building and have an effect on the inhabitants are usually the result of either site pollution (contaminated soils, etc.) or site geology (gases naturally present in the soil and sublayers).

**Landfill Gas (LFG)**. LFG is produced during the decomposition of putrescible materials in landfills and the breakdown of organic materials in soils by microorganisms. LFG is typically 40 to 60 percent methane (CH4), with the remainder consisting of carbon dioxide (CO2) with limited amounts of nitrogen, oxygen, and other compounds. Methane is a greenhouse gas that has 21 times more of an impact on climate change than carbon dioxide. LFG must be removed from the landfill to avoid odors, and to limit the migration of methane to the atmosphere or nearby structures, which can result in an explosive hazard.

**Radon.** Radon is a radioactive gas found naturally in the environment. It is produced by the decay of uranium found in soil, rock or water. Radon is invisible, odourless and tasteless and emits ionizing radiation. When radon escapes from the earth into the atmosphere, it is diluted to such low concentrations that it poses a negligible threat to health. However, when radon is confined to enclosed or poorly ventilated spaces like buildings, it can accumulate to high levels and may pose a health risk.

**Volatile Organic Compounds (VOCs).** VOC's are organic compounds containing one or more carbon atoms that have high vapor pressures and therefore evaporate readily to the atmosphere. There are thousands of compounds that meet this definition. Some, such as benzene and formaldehyde, are considered toxic and can affect health. A major source of man-made VOCs are solvents that are used in paints and protective coatings. VOCs come from human activities such as the production, storage, transport, processing, use and combustion of natural gas, coal and petroleum and its sub-products.

## SUBSLAB DEPRESSURIZATION

Subslab depressurization (SSD) aims to reduce building occupants' exposure to toxic gases from the soil. To do so, a gas collection network is installed under the entire slab and connected to an exhaust pipe, 100 mm (4 in.) minimum diameter, installed vertically through the floor to the roof. In order to prevent subsurface vapors from entering homes and other buildings, mitigation solutions can be achieved by passive or active SSD. In a passive SSD system, the gas is drained from under the slab by the drainage system to a collector pipe connected to a vent, which extracts the gas from the building by natural draft. An active SSD system is created by adding a fan to the drain vent of a passive system to increase the extracted flow and achieve a lower sub-slab air pressure relative to indoor air pressure.

## MULTI-LINEAR DRAINAGE GEOCOMPOSITE

### Geocomposite Description

Draintube multi-linear drainage geocomposite (terminology as per ASTM D4439) is composed of non-woven geotextiles that are needle-punched together with perforated, corrugated polypropylene mini-pipes regularly spaced inside and running the length of the roll. The mini-pipes have two perforations per corrugation at 180˚ and alternating at 90˚ (see Figures 1 and 2)

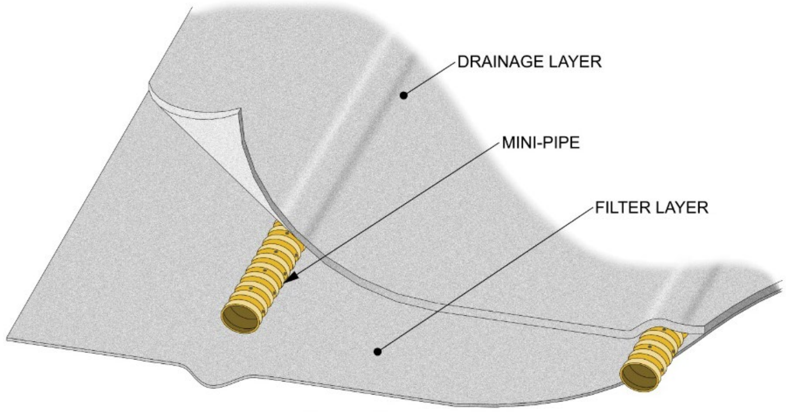


**Figure 1. Geocomposite description**

**Figure 2. Roll of Draintube**

The mini-pipes have a pipe stiffness of 5% deflection over 3000 kPa (435 psi) (ASTM D2412). Saunier et al. 2010 has shown that the flow capacity of the Draintube multi-linear drainage geocomposite is not load or time sensitive when confined. Creep and geotextile intrusion reduction factors can be taken equal to 1.0.

**Design Software**

A design software, Lymphea, has been developed by LIRIGM (*Laboratoire Interdisciplinaire de Recherche Impliquant la Géologie et la Mécanique*) at the University of Grenoble (France) in collaboration with Afitex and validated by large scale tests (Faure et al., 1995). It can be obtained from the manufacturer. Equations governing the gas collection in the software have been explained by Steinhauser et al., 2015. Results have been found similar to low-pressure Muller equations.

The gas discharge capacity of the mini-pipes of the geocomposite is expressed by the formula:

$$(q_p)_g = \alpha (i_g)^n$$

where:
$(q_p)_g$ = gas discharge capacity of the mini-pipe
$i_g$ = gradient
n,α = constants function of the type of gas and the mini-pipe

Gas flow in the geotextile component of the tubular drainage geocomposite is laminar and then can be calculated with the Darcy's law. The transmissivity in the geotextile layer for a gas can be calculated from its water transmissivity using the following expression:

$$\theta_g = \theta_w \left( \frac{\mu_w \gamma_g}{\mu_g \gamma_w} \right)$$

where:
θ = transmissivity ($\theta_w$ for water, $\theta_g$ for gas);
μ = dynamic viscosity ($\mu_w$ for water, $\mu_g$ for gas); and
γ = unit weight ($\gamma_w$ for water, $\gamma_g$ for gas)

The design software combines these equations to calculate the head loss in the entire geocomposite function of the flow to evacuate, the geometry of the project (drainage length, slope, loads applied, distance between collectors, etc.), the characteristics of the gas (density, dynamic viscosity, etc.).

**Installation**

The geocomposite is delivered in rolls and unrolled directly on the subgrade soil. Connections between rolls are achieved with overlaps of the geotextile layers and connections of the mini-pipes with couplers (see Figure 3).

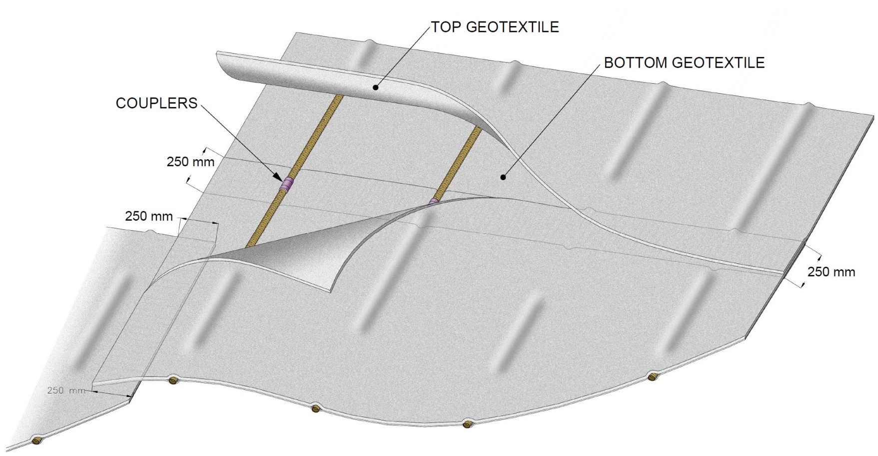


**Figure 3. Geocomposite connection**

The multi-linear drainage geocomposite is connected to a gas collector pipe and/or exhaust pipe. In active subslab depressurization systems, a fan-powered vent will be added to the exhaust system. The connections between the tubular drainage geocomposite and the collector pipe is achieved using the Quick Connect System for better gas suction in the overall SSD system, as shown in Figure 4.

**Figure 4. Connection to the collector pipe**

Depending on the function of the project, the type of gas and its expected concentration, a geomembrane can be installed above the product (see Figures 5 and 6). A plastic sheet conforming with ASTM E1745 is often installed under concrete slab but more performing geomembranes can be considered especially in presence of VOCs. Multi-layers true gas barrier geomembranes with an Ethylene Vinyl Alcohol (EVOH) core co-extruded between polyethylene (PE) layers are now available. EVOH exhibit much lower gas permeability characteristics with an order of magnitude of $10^3$ to $10^4$ compared to HDPE geomembranes (Kelsey, 2014).

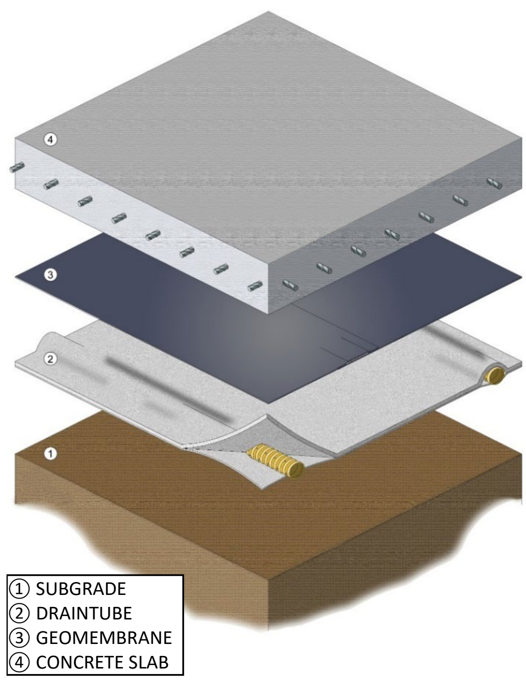


**Figure 5. Typical cross section**

**Figure 6. SSD installation under geomembrane**

## MULTI-LINEAR EFFICIENCY AS PART OF THE SSD

The aim of the gas drainage layer is to migrate gases to the collector pipes and then outside of the building through exhaust pipes. This exhaust system avoids the accumulation of gas under the slab that could eventually infiltrate the building, and the SSD system may be installed in a passive or an active configuration depending on the goals of the project.

### Passive SSD

Figure 7 gives the gas discharge rate per unit area of a tubular drainage geocomposite (20 mm diameter mini-pipes positioned every 1 m (40 in.)) as part of a passive SSD system, considering drainage lengths for different underground gases (CO2 and CH4) and several exhaust heights Δz: 1 m (3 ft), 5.5 m (18 ft) and 25 m (82 ft).

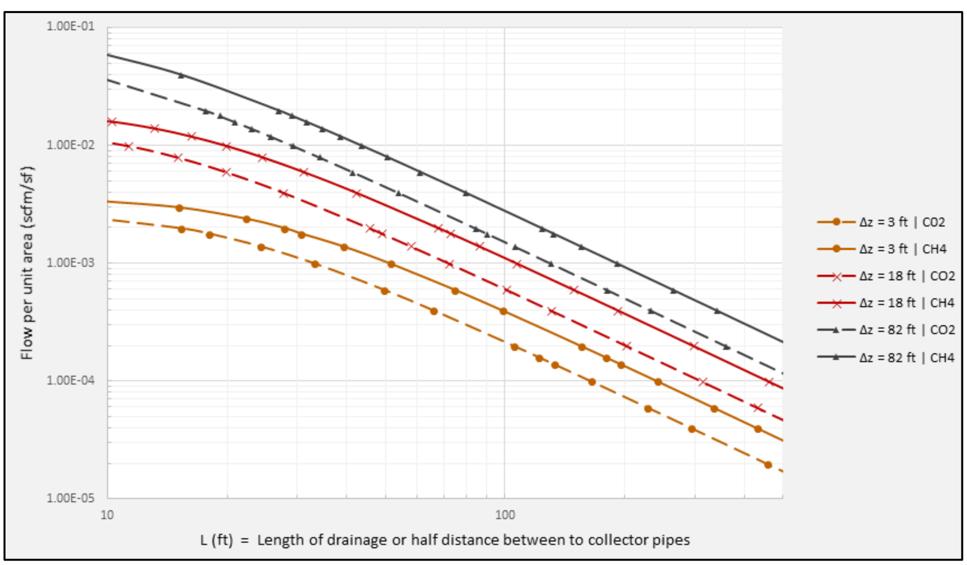


**Figure 7. Discharge capacity of a specific multi-linear drainage geocomposite in passive condition for several gases**

Given the type of gas, the flow rate to be drained on site and the exhaust height, the figure indicates the maximum drainage length of the specific tubular drainage geocomposite. If a higher flow rate discharge capacity or a longer drainage length is needed, a tubular drainage geocomposite with larger mini-pipes and/or a higher density of mini-pipes per unit width can be considered.

**Active SSD**

Figure 8 gives the $CH_4$ gas discharge rate per unit length of collector pipe of a tubular drainage geocomposite with 20 mm diameter mini-pipes positioned every 1 m (40 in.) as part of an active SSD system in relation to the length of drainage, or the half distance between two collector pipes, and the negative pressure applied. Flow and head losses are governed by the geocomposite mini-pipes and considered in the calculations. Head losses in the collector pipes and their connections are neglected.

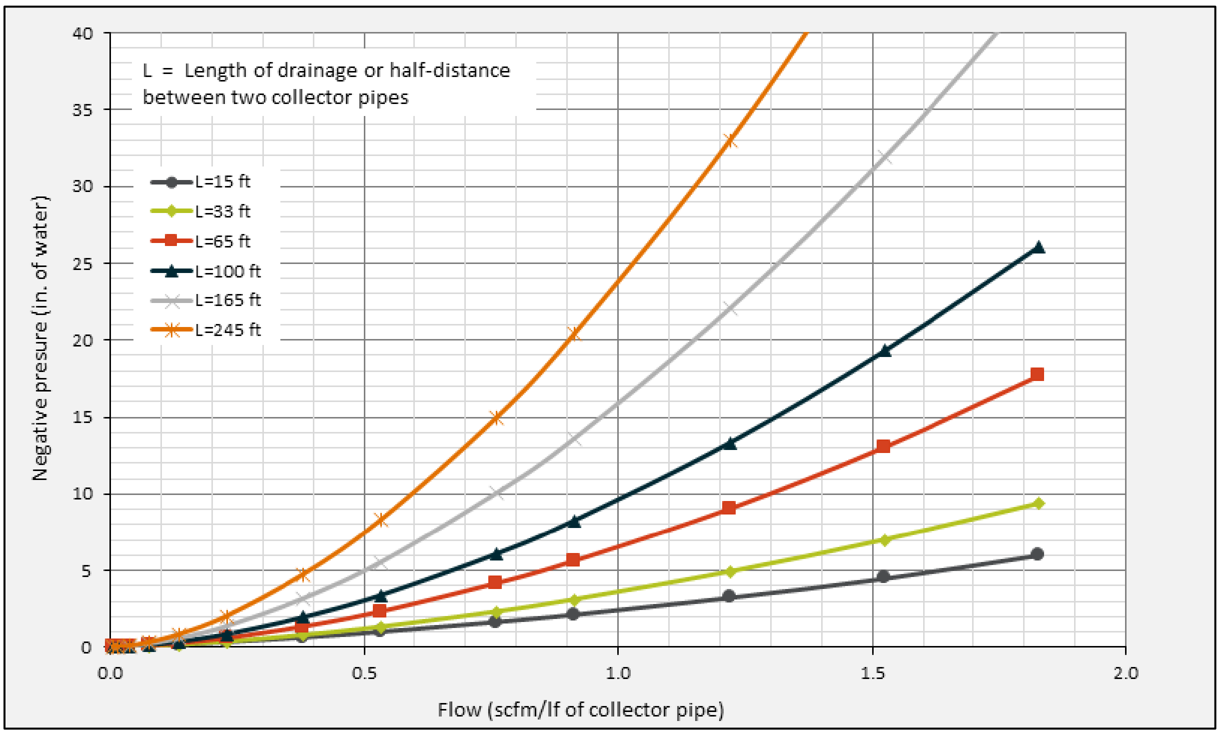


**Figure 8. Discharge capacity of a specific multi-linear drainage geocomposite in active condition as a function of negative pressure applied**

Given the distance between two collector pipes and the negative pressure applied, the figure indicates the maximum flow collected by the specific tubular drainage geocomposite per unit width of collector pipe. If a higher flow rate discharge capacity or a longer drainage length is needed, a tubular drainage geocomposite with larger mini-pipes and/or a higher density of mini-pipes per unit width can be considered.

**Comparison With a Granular Layer**

The tubular drainage geocomposite is used instead of the granular layer and perforated-pipe network traditionally considered for subslab depressurization under buildings. Figure 9 compares the gas flow capacity of a tubular drainage geocomposite with 20 mm diameter mini-pipes positioned every 1 m (40 in.) in passive conditions with that of crushed stone layers of different thicknesses for different drainage lengths.

Gas flows were calculated using an exhaust height of 1 m (3 ft.) above the drainage layer. The length of drainage is the maximal distance between the geocomposite and the collector pipe. If the geocomposite is connected on both sides to a collector pipe, the length of drainage will be half the distance between the two collector pipes.

The granular material considered is a 20 mm (3/4 in.) diameter washed crushed stone with an air hydraulic conductivity obtained from its water hydraulic conductivity of 5.0 cm/s and a ratio between water conductivity and air conductivity of 14.8 (from Richardson et al. 2000).

Figure 9 shows that the tubular drainage geocomposite permits an air flow per unit length of collector pipe 15 to 50 times superior to that of a 100 mm (4 in.) thick granular layer.

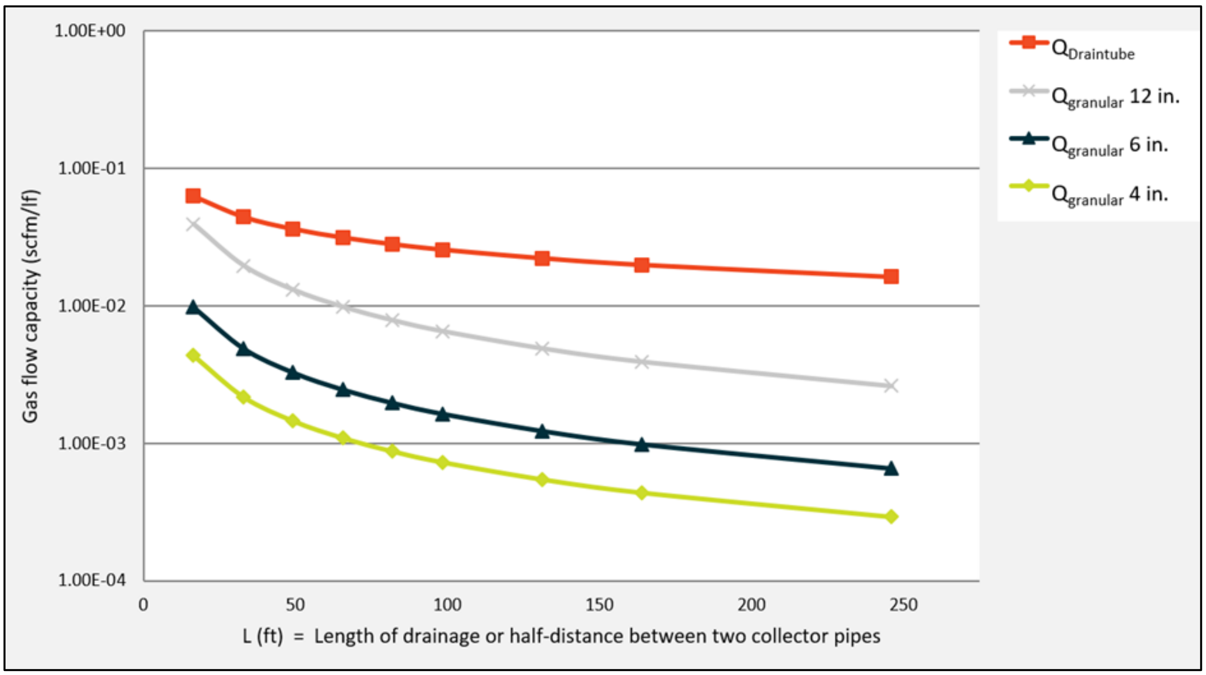


**Figure 9. Gas flow capacity of a granular layer compared to a specific multi-linear drainage geocomposite in passive condition**

## ENVIRONMENTAL AND SOCIAL FOOTPRINT

In replacement of a granular drainage layer, multi-linear drainage geocomposites offers same or better performance for underground gas collection in SSD systems. In term of Green House Gas emissions, geocomposites save up to 85% of emissions, mostly due to less excavation being needed during installation compared to a granular drainage layers and less heavy vehicle use in evacuating soil and transporting gravel (Durkheim et al, 2010).

The geocomposite solution reduces drastically the related costs because there is no soil excavation needed compared to a gravel layer and so no fees for placement of the excavated polluted soil in a waste facility.

Last but not least, SSD systems are most often required in high-density population areas (e.g. new construction in old industrial zones). The use of a multi-linear drainage geocomposite reduce the social impact on neighboring populations by limiting construction traffic and reducing works duration.

## CONCLUSION

Tubular drainage geocomposite applications offers multiple advantages over granular drainage layers for subslab underground gas collection. Their installation is simple, requiring less excavation works and relatively low skilled work. Additionally, in terms of greenhouse gas emission, social acceptability and economic competitiveness, the system has more positive assets than its conventional counterpart. Tubular drainage geocomposites can be used for passive or active subslab depressurization system and design tools are available to assess the collected flow of gas for each specific project.

## REFERENCES


ASTM D2412. Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading, *American Society for Testing and Materials*, West Conshohocken, PA, USA.

ASTM D4439. Standard Terminology for Geosynthetics, *American Society for Testing and Materials*, West Conshohocken, PA, USA.

Durkheim Y. and Fourmont S. (2010). Drainage geocomposites: a considerable potential for the reduction of greenhouse gas emission, *9th International Conference on Geosynthetics*, Guaruja, Brazil.

Faure Y.H. and Auvin G. (1995). Gas drainage by geocomposites, *Rencontres 95*, Beaunes, France

Kelsey C. (2014). Advances in barrier geosynthetics, *Civil and Structural Engineer magazine*, January 2014 edition.

Richardson G. (2000). Gas transmission in geocomposite system, *GFR Magazine*, Vol. 18, No. 2.

Saunier, P., Ragen, W. and Blond, E. (2010). Assessment of the resistance of drain tube planar drainage geocomposites to high compressive loads. *9th International Conference on Geosynthetics*, Guarujá, Brazil, Vol3.

Steinhauser E., Fourmont S. (2015). Innovative approach to landfill gas collection and control, *Geosynthetics 2015*, Portland, OR, USA, pp 283-290.