# Lateral landfill gas migration : characterization and preliminary modeling results

Olivier Bour, E. Taffoureau, R. Therrien

# LATERAL LANDFILL GAS MIGRATION: CHARACTERIZATION AND PRELIMINARY MODELING RESULTS

O.BOUR*, E. TAFFOUREAU** AND R. THERRIEN°

**INERIS, Department of Waste and Contaminated Sites, 60 550 Verneuil-en-Halatte, France*
***ESEM, University of Orleans, Orléans, France*
*° Département de géologie et génie géologique, Université Laval, Sainte-Foy, Canada*

SUMMARY: Lateral landfill gas migration occurs in the surroundings of a MSW landfill with capped old waste cells. Three areas were identified by poor vegetation growth. Methane flux chamber measures confirm the extent of these areas, as observed in the cultivated land. These measures and some complementary physical measures were used to build a conceptual model of lateral landfill gas migration in the geological layer. Prior to drilling new boreholes on the site, a preliminary simplified model will be built with the numerical code TOUGH2-LGM. A description of the geological units, methane flux and the results of the preliminary modeling are presented. The aim of this work is to identify the key parameters used to predict the travel distance of landfill gas.

## 1. INTRODUCTION

The estimation of lateral migration of landfill gas (LFG) is necessary to predict fires and explosion hazards and damages for the environment. Lateral LFG migration occurs preferentially in the case of old cells without sealing. In France, capping of old cells is common because of current French landfill regulations. Capping stops the upward migration of LFG and requires a LFG recovery network. However, drainage of LFG can be more difficult to use in the case of old cells, where the degree of saturation of the waste and mixing of the waste with fine grained soils could reduce the permeability and the capacity of a collection network. In this case, lateral LFG migration could occur, especially in the case of semi-permeable to permeable soil with buried waste.

Investigations of methane flux and composition of the gas in borehole are usually conducted to estimate LFG travel distance. Modeling of methane production and migration can help predict the methane plume migration in the soil (Poulsen & al., 2001). That type of modeling requires detailed characterization of soil properties for the entire vadose zone concerned with the plume migration. For this project, it was chosen to perform preliminary modeling of the LFG migration and focus field investigation on the upper geological layer to reduce both costs and time required.

## 2. CHARACTERIZATION OF THE MIGRATION

### 2.1 Site description

The landfill site was located in Malleville-sur-le Bec (Eure region, France). The annual capacity of the site is approximately 70 000 tons. Exploitation began in 1971 in the south area, where waste was buried without building a compacted clay liner at the bottom of the cells. Exploitation has been ongoing since 1994 within cell 1 (but with a bottom seal) as well as within the north area of the site. After capping the old cells with a geosynthetic liner, areas of poor crop production (zone Z1, Figure 1) have appeared in the vicinity of the site. The landfill was then equipped with a LFG collection network but because drainage in the old cells was poor, they were not connected to the collection network in the first years after the deposit of the waste. The study of a landfill site began in 2001 with the investigations of two different diminishing crop production areas, zone Zl and zone Z2 (Figure 1).

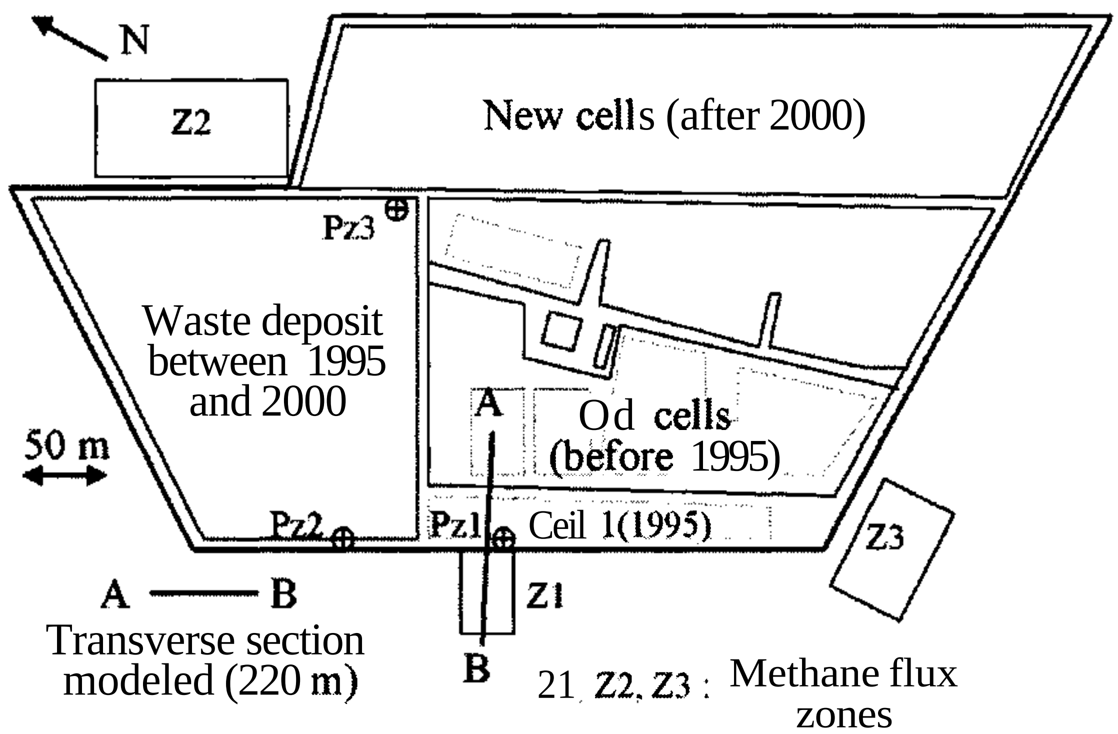


Figure 1. Scheme of the location of the crop damage and transversal section studied.

The site was initially exploited for clay and later filled with domestic waste. The geology at the site consists of, downward from the land surface :

- A superficial cover of silty clay loam ;
- A residual flint clay layer ;
- A chalk aquifer.

The thickness and the permeability of the first two layers vary within the site. The log of previous boreholes reveals that the thickness of the silty clay loam generally decreases from north to south. The thickness of the residual flint clay is approximately 12-14 meters, but the variation in thickness for the site is less known than that of the upper silty clay loam. Large variations of the thickness and permeability of the two top geological layers are likely to occur in the site. Several decimetric layers of flint blocs almost without clay could also be observed in the residual flint clay layer. The permeability of the silty clay loam and the residual flint clay range respectively from 1. $10^{-6}$m/s to 3. $10^{-8}$ m/s and from 3. $10^{-7}$ m/s to 1. $10^{-9}$ m/s in the north part of the site. A rising trend for the silty fraction from east to west was also observed. Additional investigation of the top layer with manual auger in the center of the zone 1 confirms these trends.

The rain water reaches the lower chalk layer. The water table is located 75 meters below the ground level in the chalk aquifer. The contrast of permeability between the chalk aquifer and the more clayey level of the residual flint clay could probably permit a temporary thin accumulation of groundwater. This hypothesis will be used later when we focus our attention on the first two geological layers in the vadose zone (Figure 2).

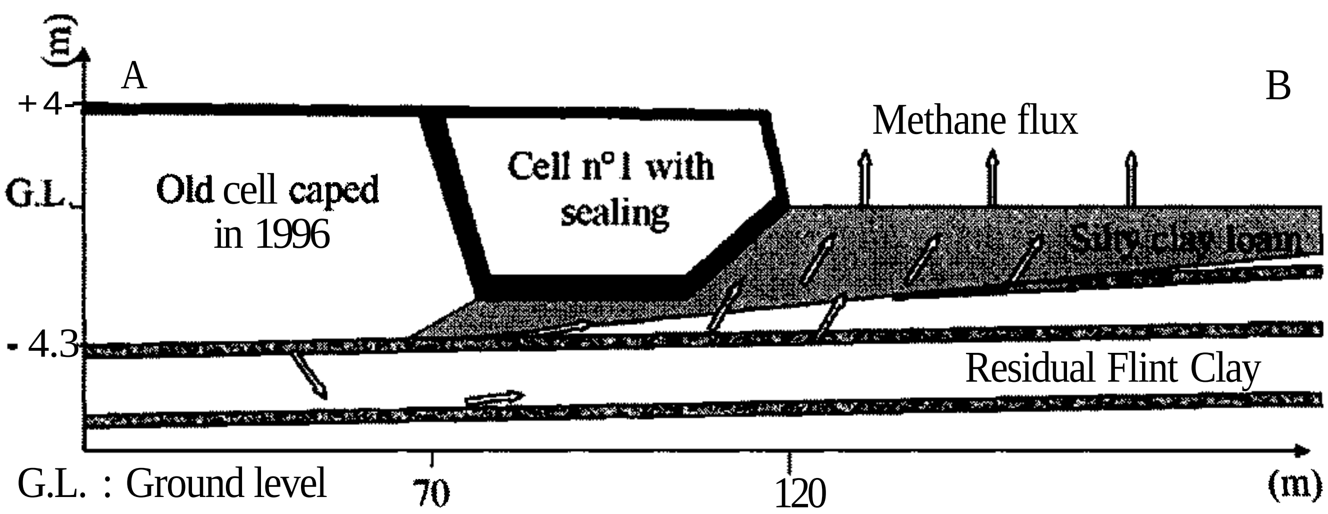


Figure 2. Geological and conceptual scheme of the lateral LFG migration in the transversal section A –B.

## 2.2 **Flux measures**

The flux chamber method (Savanne & al., 1997) was used in October 2001 and August 2002 to investigate methane flux coming from the surface in the area of the crop damage. At each measure location an area of 0.25 $m^2$ was caped by a chamber with recirculating gas. A flame ionisation detector enables to observe the enrichment of methane in the chamber. In the north area (zone Z1), measures were located on a 5 meters spacing grid which covers the area of the crop damage and the surface between the major outlines. The methane flux measures range from 0 to 82 $ml/min/m^2$. In zone Z2, Z3 transects with a 10 meters spacing between measures were investigated. The methane flux measures range from 0 to 90 $ml/min/m^2$ but there were only 6 measure points with positive values and two hot spots of methane flux. The maximum distance between a hot spot of methane flux and the landfill limit reaches 80 meters. These methods demonstrate that, during the first campaign in October, there was good agreement between the area of the crop damage and the occurrence of the methane flux, especially in the zone 1 (wheat culture).

The first crop damages are located in the zone Z1 and are contemporaneous with the capping of the old cells with liner. The source of LFG is also probably coming from one of these old cells. Under this assumption, the LFG should migrate perpendicularly and under new cell n°1. LFG reaches the distance of 130 meter for the farthest hot spot of methane. Travel distance of several hundred meters have been reported in the literature (Nastev & al., 1998). For the other areas (zones Z2 and Z3), sources are more difficult to locate. Nevertheless it is more than likely that preferential migration is associated with the flint blocks layers located in the upper part of the residual flint clay and the more silty fraction of the silty clay in the west area. A documented report of an explosion that occurred when drilling piezometer Pz3 in this material confirms this assumption.

### 2.3 Properties of the vadose zone material

The first meter of the silty clay loam was investigated in order to obtain physical parameters and a secondary parameter correlated with the methane flux. Water content of undisturbed soil samples was investigated in three profiles. Capillary pressure was also measured by tensiometers. These parameters permit to adjust Van Genuchten parameters for the silty clay loam. A geophysical campaign was also conducted in zones Z2 and Z3 to detect the influence of more resistive material in the superficial layer. A geophysical survey done with a EM 38 device was not conclusive in zone Z2, most probably because of recent ploughing of the land. In zone Z3, the contrast was better and some correlation could be done between the geophysical and flux measures. The only hot spot of methane flux was located in the transitional stratum between the silty clay loam and a more silty layer with some flints (Figure 3).

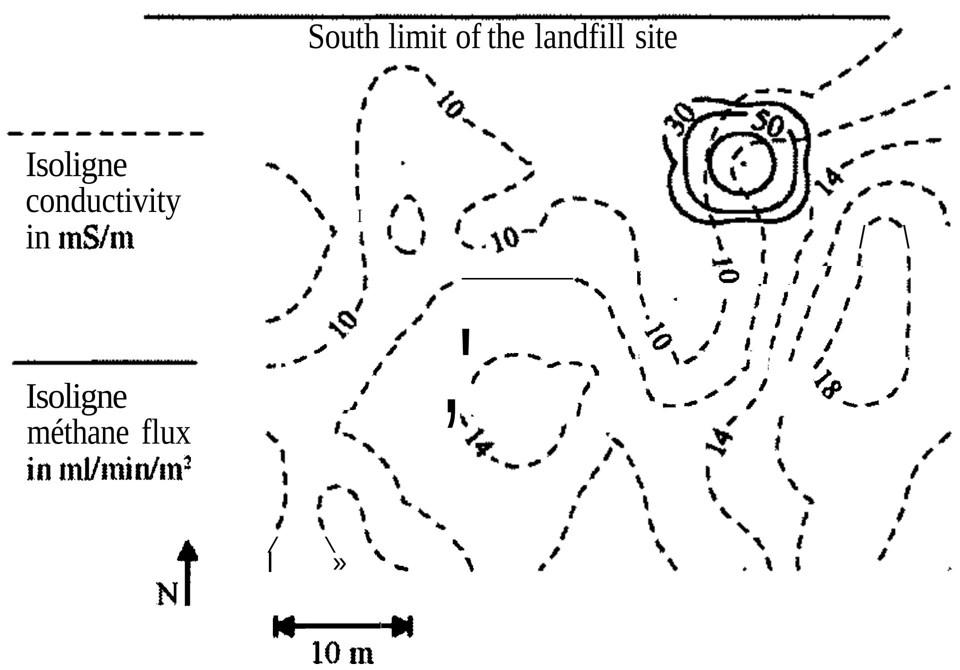


Figure 3. Scheme of the location of the hot spot of methane flux in the Z3 zone.

## 2. PRELIMINARY MODELING OF LFG LATERAL MIGRATION

### 2.1 Model and boundary conditions

The aim of this preliminary modeling was to simulate LFG production and migration in the soil under the new cell and in the area of the field (zone Z1). Limited data is available to characterize the buried refuses in the old cells and the flint strata. Due to the restricted data set used, the major aim was to better understand the migration along the transverse section. The simplified assumptions used do not permit to compare the distribution of the methane flux along the transverse section and the flux methane measures. Nevertheless, knowledge of the date of the deposit and the description of the waste permits the use of a first order kinetic model for the rate of methane production, with a half life equal to 7 years. The lack of data concerning the location of the flint strata permits only to use a simplified homogeneous description of the geological material.

For this study, steady state water saturation is assumed. Water infiltration in the field was modeled with a medium infiltration rate of 100 mm/year, which is approximately half of the real annual recharge. Actually, recharge at the site occurs only during half of the year and the net infiltration rate is null during the month of the flux measures. Also the choice of a medium rate permits to maximize the gas saturation of the soil void and then the relative gas permeability.

The numerical model TOUGH2-LGM used was developed by Nastev & al. (1998) to simulate LFG production and migration. The model contains a new equation of state to account for 4 fluid components (air, water, methane et carbon dioxide) and heat. An average temperature of 10 °C was chosen for the entire profile. The mesh of the transverse section used 18 grid blocks in the vertical direction and 28 grid blocks in the horizontal direction. A saturated bottom boundary with no charge of water was used in order to limit the migration in the first 12 m modeled (Figure 3). The waste located above the ground level were supposed not to contribute to the migration. A zero flux limit was also chosen for the left lateral boundary concerning the waste and silty clay loam left column.

Table 1 - Physical parameters used for the simulations (Parameters for waste from Nastev & al. (1998))

| Parameters | Waste | Silty clay loam |
|---|---|---|
| Bulk density (kg/m$^3$) | 760 | 2030 |
| Porosity | 0.50 | 0.43 |
| Permeability (m$^2$) | 1. 10$^{-12}$ | 1. 10$^{-12}$ |
| Residual water saturation | 0.03 | 0.15 |
| Van Genuchten a (Pa$^{-1}$) | 5.10 | 3.29 |
| Van Genuchten $\gamma$ | 0.11 | 0.324 |

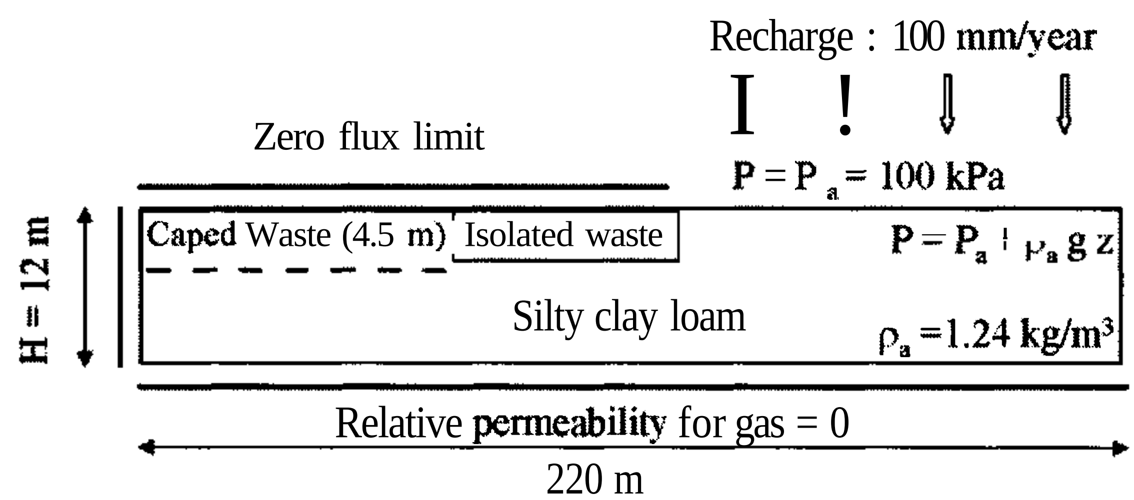


Figure 3. Scheme of the boundary conditions used for the modeling

## 2.2 **Results and discussion**

The simulation of LFG production and migration starts in 1996 (To = date of the capping) and runs until 2003 (To + 7 years). The location of the modeled methane concentrations one year and 3 years after capping have been compared with the first observations of crop damage and with the first flux measures in 2001. The distribution of the methane concentration (Figure 4) shows that methane migrates quickly and reaches the landfill boundary in the first year after capping. Observation of methane flux directions shows that the flux was almost horizontal in the first 120 meters. Also the influence of the boundary conditions are perceptible. The methane flux direction was constrained by the boundary conditions in this part of the conceptual model. The high permeability for the silty clay loam was chosen to simulate a worst case scenario. A nearly equivalent steady state distribution of methane concentration was observed after capping. Methane concentrations greater than 1 % do not reach distances greater than a few tens of meters. In our simulations, a fraction of the methane flux reaches the boundaries of the model, which indicates that future simulations should consider a domain of larger lateral extension to reduce the influence of the right boundary condition.

A major assumption in the model is to neglect the flint stratum. Previous investigations have not always reported the presence of this flint strata for the entire profile. Future investigations with borehole drilling will be needed to validate this assumption.

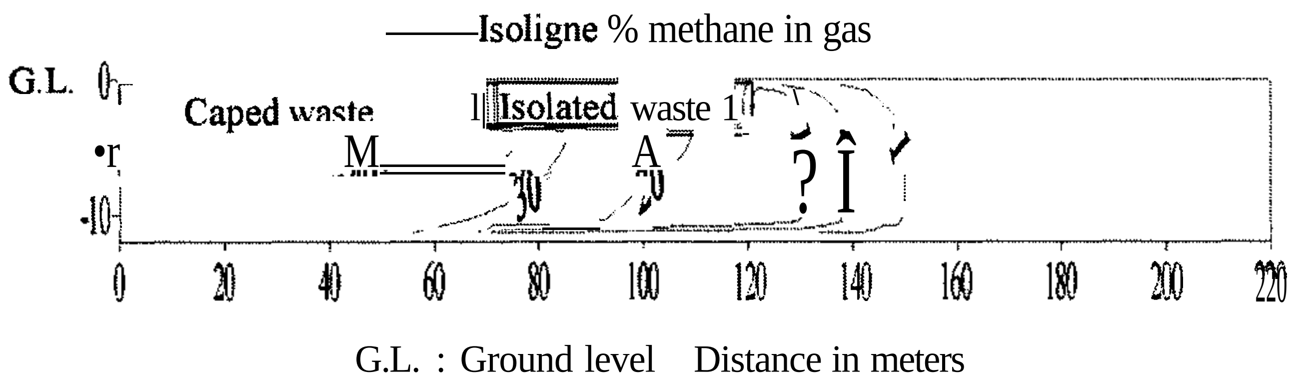


Figure 4. Distribution of the methane concentrations in the soil in the transverse section A-B, one year after capping of the old waste.

## 5. CONCLUSIONS

The flux characterization and preliminary modeling presented in this study allow a better understanding of lateral landfill gas migration. In the field, methane flux concentrated on hot spots. We need additional evidence to demonstrate the leading part of the transitional strata between the silty clay loam and the residual flint clay layer. Further studies including calibrations with the methane measures in boreholes and better description of the geological strata are necessary to improve the efficiency of the modeling predictions of the travel distance of methane.

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