3-D electrical tomography monitoring of landfill leachate reinjection

Jean Christophe GOURRY[1], Boris CHEVRIER[1], Dominique GUYONNET[1],
Sylvain MOREAU[2] and Mélanie LEMUNIER[3]
(1) BRGM, BP 36009, 3 avenue Claude Guillemin, 45060 Orleans, France
(2) Cemagref, BP 44, 92163 Antony Cedex, France
(3) CIRADE, 38 rue Jean Jaurès. 78440 Gargenville, France

Introduction

As part of the French National Agency for Research (ANR) project BIOREACTEUR, a new methodology was developed to improve electrical tomography imaging during leachate injection used to promote waste biodegradation in bioreactor landfills. To-date, only 2D imaging has been performed (Guérin et al., 2004, Moreau et al., 2007). But 2D tomography suffers from inversion artefacts due to lateral effects (Spitzer, 1990). Furthermore, 3D images can provide a better visualisation of potential preferential flows. Such flows are related to the heterogeneity of the waste body and impede the efficiency of leachate reinjection.

One of the objectives of the BIOREACTEUR project is to develop and validate a 3D electrical tomography approach with the aim of allowing a reconstruction of the volume impregnated by leachate during reinjection and a monitoring of this volume's evolution over time (during injection and drainage). According to Archie's law, a relative variation of resistivity $\Delta\rho$ reflects a relative variation in saturation $\Delta\rho / 2$, provided porosity and fluid resistivity remain unchanged. The main objective of the work presented here was to optimise the number and the geometry of measurement quadripoles, in order to obtain a measurement repetition period of 10 minutes while retaining a resolution of at least 2 m^3. In addition to the precise monitoring of waste wetting, the high acquisition speed has the advantage of providing the resistivity measurements within a very short period of time, compatible with the fluid movement kinetics. It was estimated that over the 10 min time-period, the degree of waste saturation does not evolve significantly and therefore measurements provide a quasi-instantaneous "snapshot" of waste resistivity.

Geophysical measurements

Landfill leachate was injected into a waste cell using an injection drain that was perforated along its length to provide a homogeneous distribution of fluid (Figure 1). A 3D electrode network was installed above the injection drain to confirm this hypothesis: 8 lines were separated by 3 m, each composed of 24 electrodes spaced every 2 m (Fig. 1), yielding a total of 192 measurement electrodes.

Following preliminary tests, a "multiple gradient" array (Dahlin et Zhou, 2006) was identified as providing the best signal/noise ratio without stacking, and the best spatial resolution. A total of 2720 resistivities (400 injections of current) were measured during one sequence on a 10-channel resistivity-meter (IRIS Instruments). During the injection experiment, 45m^3 of leachate were injected over a period of 3 hours. The 3D measurements were repeated every 11 minutes during the first 5 hours, and every 30 minutes until 68 hours after the beginning of injection. A total of 96 sequences were measured during this period. The 3D inversion of the data set was carried out using the Res3DInv software.

Results

Figure 2 illustrates the volume within which resistivity decreased by at least 2% with respect to the initial conditions. For each quadripole, the relative variations of apparent resistivity may increase or decrease over time. But true resistivities continuously decrease during the injection phase and increase during the drainage phase (Fig. 2). It is seen in Figure 2 that the leachate infiltrated fast into the waste, but preferentially near the bottom end of the injection drain. About 30 minutes following the start of injection, a quasi steady-state was reached and the volume of the wet bulb shows little variation after that, although degrees of saturation within the bulb continued to increase. Lateral extent of the wet bulb, with respect to the drain axis, appears to be on the order of 7-10 meters (Fig. 3). Following termination of injection (3 hours after the start) the wet bulb shrinks over a period of approximately 3 days.

Preliminary conclusions

3D electrical tomography allows a good visualisation of the volume influenced by leachate injection. Despite larger operational constraints than with 2D tomography, the 3D approach avoids the inversion artefacts involved in 2D tomography. It was possible to optimise the measurement frequency in order to allow a monitoring of the injection period. Such a method should prove useful for improving the design of bioreactor landfill leachate injection systems. It should also be possible to analyse the results of the measurements in real time, thus allowing a better control of leachate injection experiments. This is a short-term objective of the ongoing project.

References cited

Dahlin T. and Zhou B., 2006. Multiple gradient array measurements for multi-channel 2D resistivity imaging. Near Surface Geophysics, 2006 ;13-123.

Guérin, R., Munoz, M.-L., Aran, C., Laperrelle, C., Hidra, M., Drouart, E., Grellier, S. (2004) – Leachate recirculation: moisture content assessment by means of a geophysical technique, Waste Management, 24, pp. 785-794.

Moreau, S., Courant, P., Budka, A., Presse D., Bouye, J.-M. (2007) – Using electrical resistivity 2D tomography in solid waste to evaluate hydraulic performances of leachate recirculation networks in landfills. Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium. S. Margherita di Pula, Cagliari, Italy, 1-5 October 2007.

Spitzer K., 1998, The three-dimensional DC sensitivity for surface and subsurface sources; *Geophys.J.Int.*, 137, 736-746.

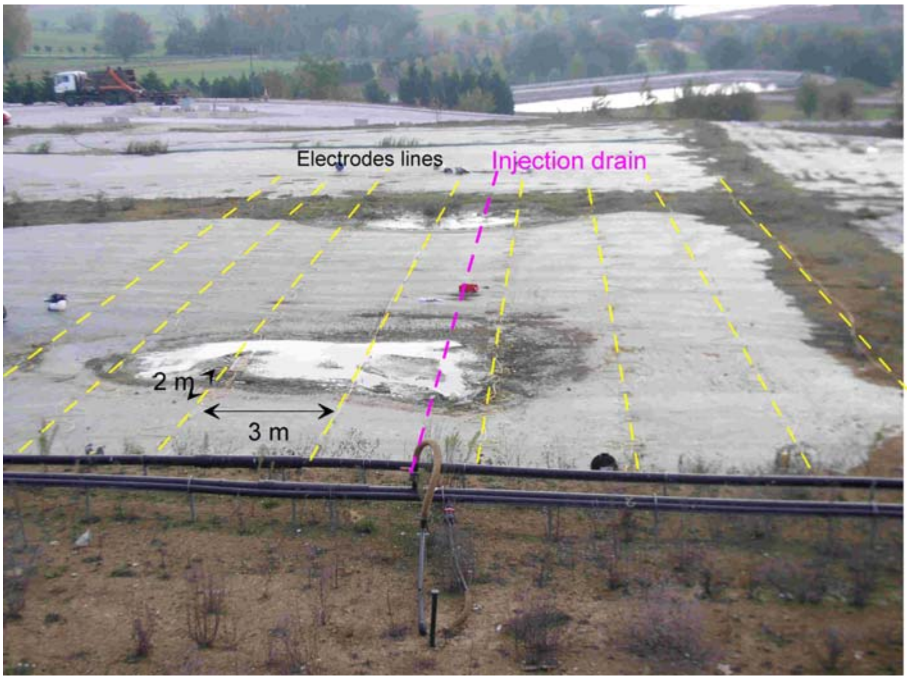

Fig 1 : Configuration of the electrode network at the cell surface

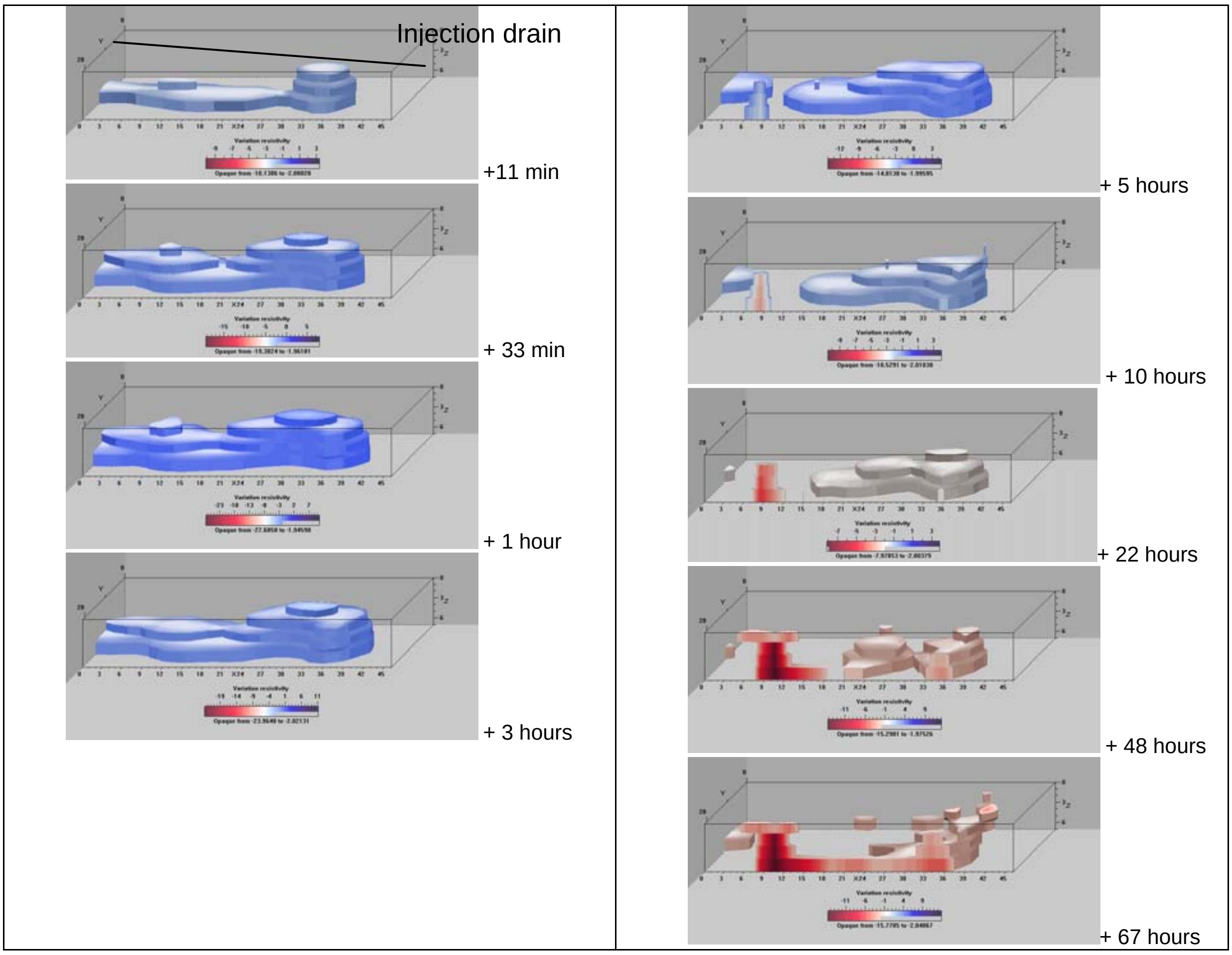

Fig 2: 3D electrical tomography imaging of leachate injection (left) and drainage (right). The envelop represents the volume where electrical resistivity has decreased of 2% compared to conditions before leachate injection.

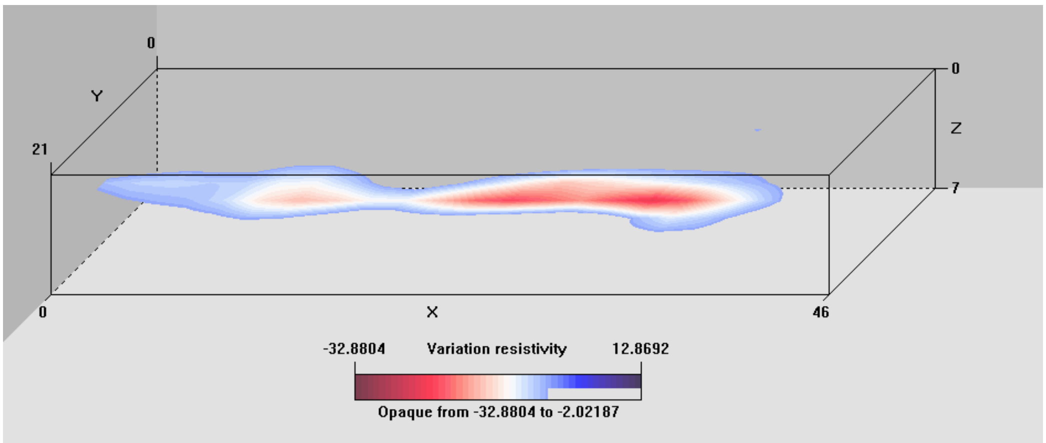

Fig 3 : Resistivity variation 2 hours after beginning of leachate injection at 3.5 m depth.