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Improvement of electrical resistivity tomography for leachate injection monitoring

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ABSTRACT

Leachate recirculation is a key process in the scope of operating municipal waste landfills as bioreactors, which aims to increase the moisture content to optimize the biodegradation in landfills. Given that liquid flows exhibit a complex behaviour in very heterogeneous porous media, in situ monitoring methods are required. Surface time-lapse electrical resistivity tomography (ERT) is usually proposed. Using numerical modelling with typical 2D and 3D injection plume patterns and 2D and 3D inversion codes, we show that wrong changes of resistivity can be calculated at depth if standard parameters are used for time-lapse ERT inversion. Major artefacts typically exhibit significant increases of resistivity (more than +30%) which can be misinterpreted as gas migration within the waste. In order to eliminate these artefacts, we tested an advanced time-lapse ERT procedure that includes (i) two advanced inversion tools and (ii) two alternative array geometries. The first advanced tool uses invariant regions in the model. The second advanced tool uses an inversion with a "minimum length" constraint. The alternative arrays focus on (i) a pole–dipole array (2D case), and (ii) a star array (3D case). The results show that these two advanced inversion tools and the two alternative arrays remove almost completely the artefacts within +/−5% both for 2D and 3D situations. As a field application, time-lapse ERT is applied using the star array during a 3D leachate injection in a non-hazardous municipal waste landfill. To evaluate the robustness of the two advanced tools, a synthetic model including both true decrease and increase of resistivity is built. The advanced time-lapse ERT procedure eliminates unwanted artefacts, while keeping a satisfactory image of true resistivity variations. This study demonstrates that significant and robust improvements can be obtained for time-lapse ERT monitoring of leachate recirculation in waste landfills.

1. Introduction

The concept of bioreactor landfill has been studied and tested since 1970 in the United States of America (USA) and for more than a decade in Europe. This technology aims at enhancing the waste biodegradation in landfills. Many studies have pointed out the potential benefits of the bioreactor approach, namely:

- A quicker stabilisation of organic content can be achieved (10–15 years compared to 30–100 years with a classical land filling operation) (Pacey et al., 1999).
- The biogas production can be improved (Hossain et al., 2003) providing a significant improvement of the efficiency of biogas power plant.
- The environmental hazard is reduced because bioreactor requires a better monitoring (Reinhart et al., 2002).
- If a leachate recirculation system is used, the volume of leachate to be treated is reduced as a part of the liquid retained by the waste matrix (Pohland, 1980; Warith, 2002).

In situ operation of a landfill as a bioreactor requires a careful monitoring and control of the operating parameters. The moisture content has a major influence on the efficiency of the methanogen bacteria (Reinhart and Townsend, 1998). The anaerobic methanogenesis is enhanced by a high moisture content that can only be reached by adding water to the waste. Indeed, under temperate climate, the waste disposed in landfill is generally too dry to ensure an optimal biodegradation. The leachate recirculation appears to be a very favourable process since it could increase the moisture content. Moreover, the leachate recirculation tends to uniform the spatial distribution of adapted micro flora. As far as an efficient monitoring of the bioreactor is concerned, measuring the water in landfills is a key issue (Imhoff et al., 2007). In particular, the optimisation of leachate injection systems remains a challenging and ongoing problem for bioreactor landfill operators. Addressing this issue requires monitoring of these systems during long term field

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