

Geo-electrical Forward Modelling Using Comsol Multiphysics At Lab-scale
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Keywords: Forward Modelling, ERT, waste, laboratory test

Leachate recirculation is a key process in the scope of operating Municipal Solid Waste (MSW) landfill as bioreactor which aims to increase the moisture content to optimize degradation in landfills. Most of studies have shown that Electrical Resistivity Tomography (ERT) can be a suitable method to study relative water content variation using 2D or 3D inversion process (Clément et al., 2011; Guérin et al., 2004; Moreau et al., 2003). ERT is usually proposed, but the interpretation of resistivity variations is not easy at field scale. Electrical resistivity is influenced by many physical and chemical parameters of the medium studied and no relationship with volumetric water content evolution is yet established for MSW. Landfill scale is not adapted to control physical parameters of waste body and study their influence on resistivity measurements. For this reason, a laboratory approach is developed for a better understanding of electrical resistivity variations of waste impacted by water content, temperature density, or biodegradation. To achieve this goal, laboratory tests were started using cylindrical test cells (Figure 1-a) but before metrological evaluation of resistivity device was necessary with numerical modelling approach using Matlab script and Comsol Multiphysics software 4.2.

The script tool developed by our team for laboratory test cell is named F3D-Lab, for Forward 3D Laboratory. ERT method is based on non-intrusive resistivity measurements, between a set of electrodes located on the circumference of a predetermined cylinder with a conductivity distribution. The main focus in this presentation is to describe the electromagnetic module in Comsol Multiphysics to model ERT measurements by evaluating the electrical potential inside the cylindrical laboratory test cell. The equations of electric currents and the modelling approach for 3D geometries are considered.

In the first part, authors show how F3D-Lab script could be used to calculate the apparent resistivity data of a resistivity distribution in test cell equipped with several electrodes. The apparent resistivity data come from the evaluation of the potential difference between two electrodes induced by the normal current density injected between two others electrodes. One advantage of Comsol Multiphysics 4.2 is to represent electric field distributions using AC/DC module (quasi-stationary electromagnetic field with the theory of electromagnetic field). Another advantage is to design complex geometries (electrodes and cylindrical cells) for ERT modelling in homogeneous or heterogeneous resistivity mediums and to allow automatic calculations for many quadrupoles with Matlab scripts. The different modelling steps proposed by F3D-lab are the following:

1. Drawing the laboratory cell geometries diameter and high;
2. Selection of the shape and position of electrode using .txt file;
3. Automatic design of laboratory test cell geometry with electrodes implemented;
4. Generating adapted mesh as function of electrode size;
5. Choice of the electrical properties in the domains (conductivity distribution);
6. Choice of the boundary conditions (normal current density, electric insulation, current conservation, initial potential, ground);
7. Resolution and calculation of the field distribution for quadripole array;
8. Post-processing capabilities in Matlab to evaluate voltages and apparent resistivity.
9. Data file edition for inversion software.
10. Adding Gaussian noise, for more realistic apparent resistivity

In the second part, the authors present data from numerical simulation and test in laboratory cell for a homogenous media to validate our modelling tool. The results compare the geometric factors evaluated by the both methods ($k_{\text{simulation}}$ and $k_{\text{lab scale}}$). The relative difference between $k_{\text{simulation}}$ and $k_{\text{lab scale}}$ is lower than 3% (Table 1).

A	B	M	N	$k_{\text{simulation}}$	Simulated geometrical factor	$k_{\text{lab scale}}$	Measured geometrical factor	Error
1	13	5	9		0.127		0.125	1.92
5	6	7	8		0.581		0.596	2.58
5	8	9	12		0.279		0.286	2.48
5	6	11	12		0.888		0.906	1.96

Table 1: Example of comparison between simulated geometrical factor with Comsol Multiphysics 4.2 and measured geometrical factor in laboratory

In the third part, authors demonstrate the possibility of the modelling tool to take into account in the inversion process the electrode shape at laboratory scale, by considering the position of an equivalent point where the geometrical factor is the same (Figure-2).

In the last part, we demonstrate how F3D-Lab enables to calculate apparent resistivity for all resistivity distributions. The confidence of inversion software (using different options) can be evaluated comparing bulk resistivity with the interpreted resistivity obtained by the inversion process.

According to the results from numerical modelling tool, following perspectives are possible: evaluation of inversion softwares, distribution of a complex resistivity in 2D and 3D, drawing of insulating or infinite structures. Comsol Multiphysics 4.2 and F3D-lab Matlab script allow to draw a complex geometry of insulating object, to add a complex distribution of resistivity inside cylinder or to change the laboratory test cell shape: cylinder, box, . The new geophysical studies s available are:

- Developing field scale Matlab script measurement;
- Combining different forward modelling geophysical methods in the same Matlab script tool (ERT, TDEM and EM);
- Combining approach using geophysical measurement and hydrodynamical simulation.

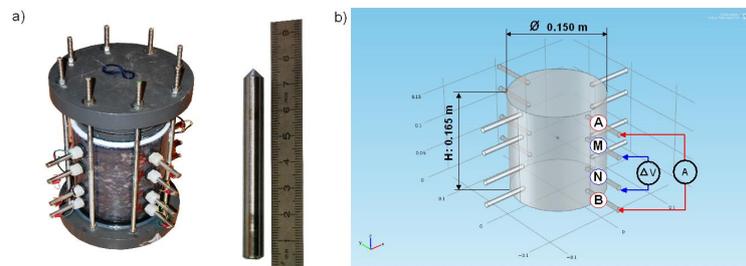


Figure 1: a) Test cell and electrodes; b) Electrical resistivity measurements principle (AB, current injection electrodes; MN electric potential electrodes).

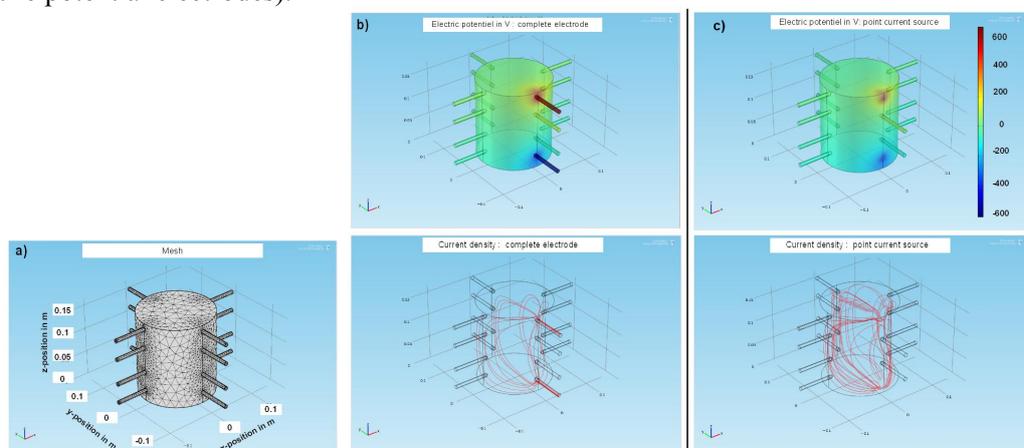


Figure 2: a) Test cell mesh used for calculation; b) electric potential and current density for complete electrode; c) electric potential and current density for point node electrode.

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