INTEGRATING ELECTRICAL RESISTIVITY TOMOGRAPHY AND SOIL SAMPLING METHODS TO CHARACTERIZE A SOLID WASTE LANDFILL AREA

G. Morelli, G. Corsini
Dept. of Information Engineering, University of Pisa, Italy ,
L. Di Tola, R. Pini, G. Vigna Guidi
C.N.R. Institute for Soil Chemistry, Pisa, Italy),
M. Miletto, M. Ferguglia, G. Pogliano, G. Catanzariti
Earth Sciences Dept., University of Torino, Italy
F. Franceschini, A. Scozzari, R. Corsi
STEAM srl, Pisa, Italy

INTRODUCTION

A municipal solid waste landfill, located 35 Km east of Pisa (Italy), was selected to experiment the application of Electrical Resistivity Tomography (ERT) to detect and delineate the plume of contamination caused by the absence of any natural or artificial protection for the underlying confined aquifer. ERT results have been supported and checked against geochemical data, hydrogeological data and measurements of soil physical properties.
Standard surface resistivity surveys were followed by the collection of innovative surface and cross-borehole ERT data over 7 two-dimensional planes, using a recently developed (STEAM srl, Pisa) hardware system, capable of addressing modules of 36 electrodes and energizing the ground with a maximum of 500 V and 1.2 A. The ERT interpretation was provided by a full inversion code developed at the University of Pisa, and based on the procedures proposed in Morelli et al., 1996 and LaBrecque et al., 1996.
Measurements on core samples collected during the drilling were performed on the field using a portable Resistivity-IP-meter, developed at the University of Torino. Laboratory measurements were done at the C.N.R. Institute for Soil Chemistry and provided soil/rock physical properties (density, porosity, cation exchange capacity, soil particle size distribution, etc.) and chemical properties (COD, HC, salts concentrations, heavy metals presence, pH, etc.) on soil and fluid samples.

FIELD ACTIVITIES AND RESULTS

The landfill site consists in a dismissed couple (pit A and B in Figure 1) of municipal waste dump pits, active for over 20 years, located in the floodplain of the river Arno . The excavation of the two pits had eliminated the natural protection given by 6-7 meters of clay, so that the solid waste and the hazardous fluids have been in contact with the underlying sandy aquifer for a long time. Few groundwater and leachate monitoring boreholes were drilled in the past, inside and outside the landfill area ("PM" locations in Fig. 1). An underground low-permeability cutoff wall was installed in the last two years on the northern side of pit A, while no interventions were programmed for pit B.
The first step of the site characterization consisted in an extensive Soil-Gas survey ("SG" sampling locations in the map of the site, Figure 1), performed with probes installed using a continuous hand-boring technique, that helped, together with soil and water samples analysis, to characterize the vadose zone. The soil and gas samples collected during this stage were analyzed to detect the eventual leachate dispersion in the clayey unsaturated zone. The results

showed no noticeable trace of contamination or biogas diffusion in the low-permeability vadose zone.

A second survey used traditional geoelectrical soundings to determine the approximate locations and depths of the highly conductive anomalies due to the presence of fluids migrating from the landfill bottom. Zones of high conductivity were revealed along the northern side of both pits. Combining the information gathered in the two surveys resulted in the design of a system of 8 boreholes (MW1 -> MW8 in Fog. 1) to be used for ERT electrodes (18 per well) installation, soil/water sampling and groundwater monitoring.

Electrical resistivity is a function of the effective porosity of the soil, pore water saturation, pore water chemistry and clay particles conduction (characterized by the cation exchange capacity). All these parameters were determined by laboratory measurements on soil and fluid samples collected during the drilling of the above mentioned wells. Additional laboratory data obtained include VOC and heavy metals concentrations.

Figure 2 shows the ERT results obtained on the 2D section MW6-MW2 compared with the borehole log (refined with lab measurements) : the agreement on the very complex stratigraphy and on the presence of leachate in the aquifer is remarkable, and ERT gives information on the spatial distribution of the leachate (partly floating on top of the aquifer and partly sinking to the bottom of it) characterized by resistivities below 5 $\Omega \cdot$m.

Figure 3 shows the borehole-to-surface result obtained using well MW3 and surface electrodes around it. The comparison with the resistivities measured on the field with a portable sample-holder instrumentation is really good (Fig. 3 and 4), while the values obtained in the laboratory are all higher. This can be attributed to the analytical procedures and sampling techniques adopted (that could cause the partial loss of salts). Calculated resistivity values of the saturated sand using the Waxman-Smits equations are in good agreement with the field results.

CONCLUSIONS

The results presented in this paper show that the resistivity values reconstructed with ERT match well with the measurements made on core samples directly on the site. They are also in good agreement with the predicted resistivity values for both clean and contaminated soil. The comparison with the values yielded from laboratory measurements needs to be done carefully, taking into account the differences among the sampling and measurements techniques adopted. ERT results provided additional information on the spatial distribution of the contaminant plume in the saturated zone and in the vadose zone, thus allowing to control the pollutant migration, and to establish and optimize future remedial actions.

ACKNOLEDGEMENTS

The results presented in this paper has been obtained in the framework of the project "LIFE 1995" 95/IT/00357/TOS funded by E.C. D.G. XI.

REFERENCES

D. J. LaBrecque, M. Miletto, W. Daily, A. Ramirez, E. Owen: " *The effects of noise on Occam's inversion of resistivity tomography data* ", Geophysics , Vol. 61, No. 2, pp. 538-548, 1996.

G. Morelli, D. J. LaBrecque : " *Robust scheme for ERT inverse modeling* ", Proceedings of the 9^{th} Symposium on the Application of Geophysics to Engineering & Environmental Problems , Keystone, Colorado, 1996.

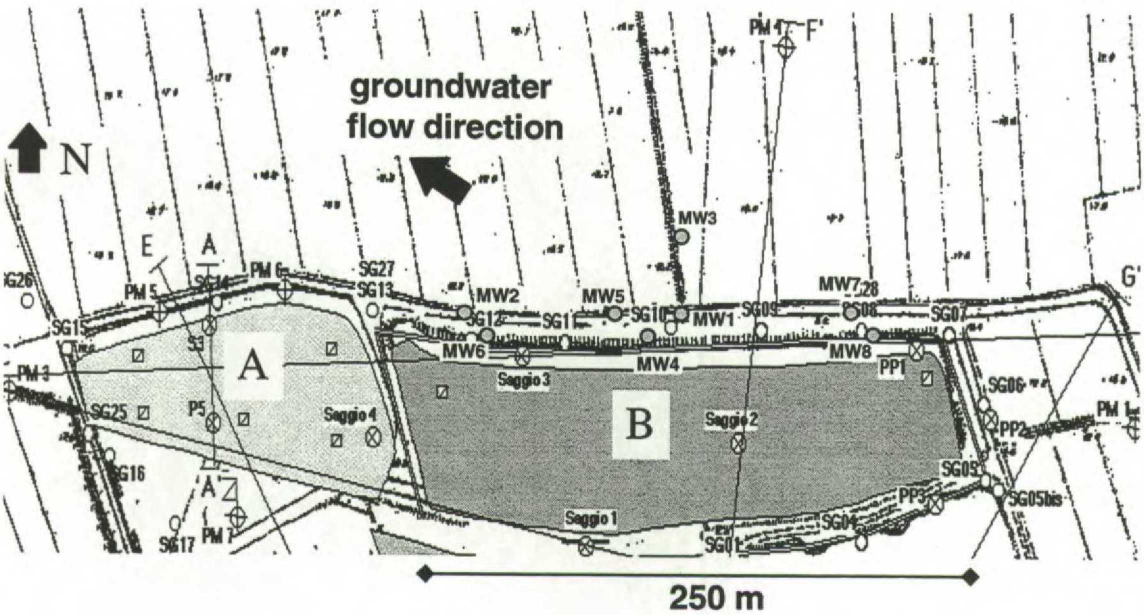

Figure 1 : Map of the landfill site with sampling and drilling locations.

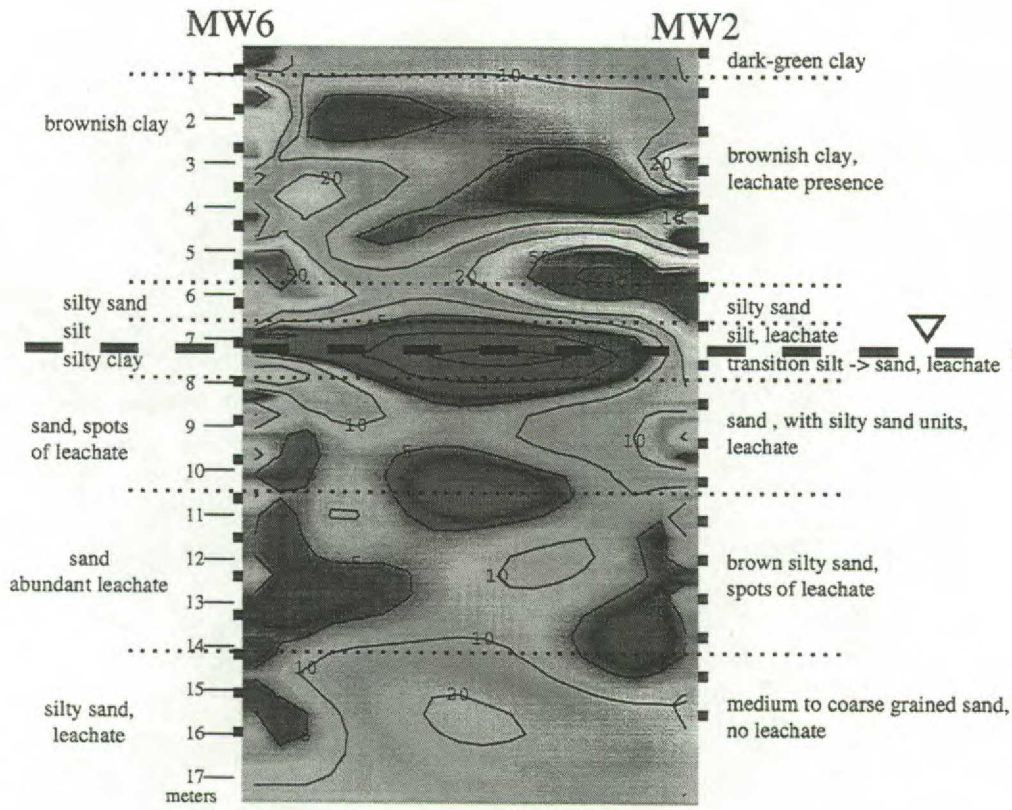

Figure 2 : Comparison of Cross-Borehole ERT results (resistivity in Ohm*m) between wells MW2 and MW6 and continuous boring core samples analysis.

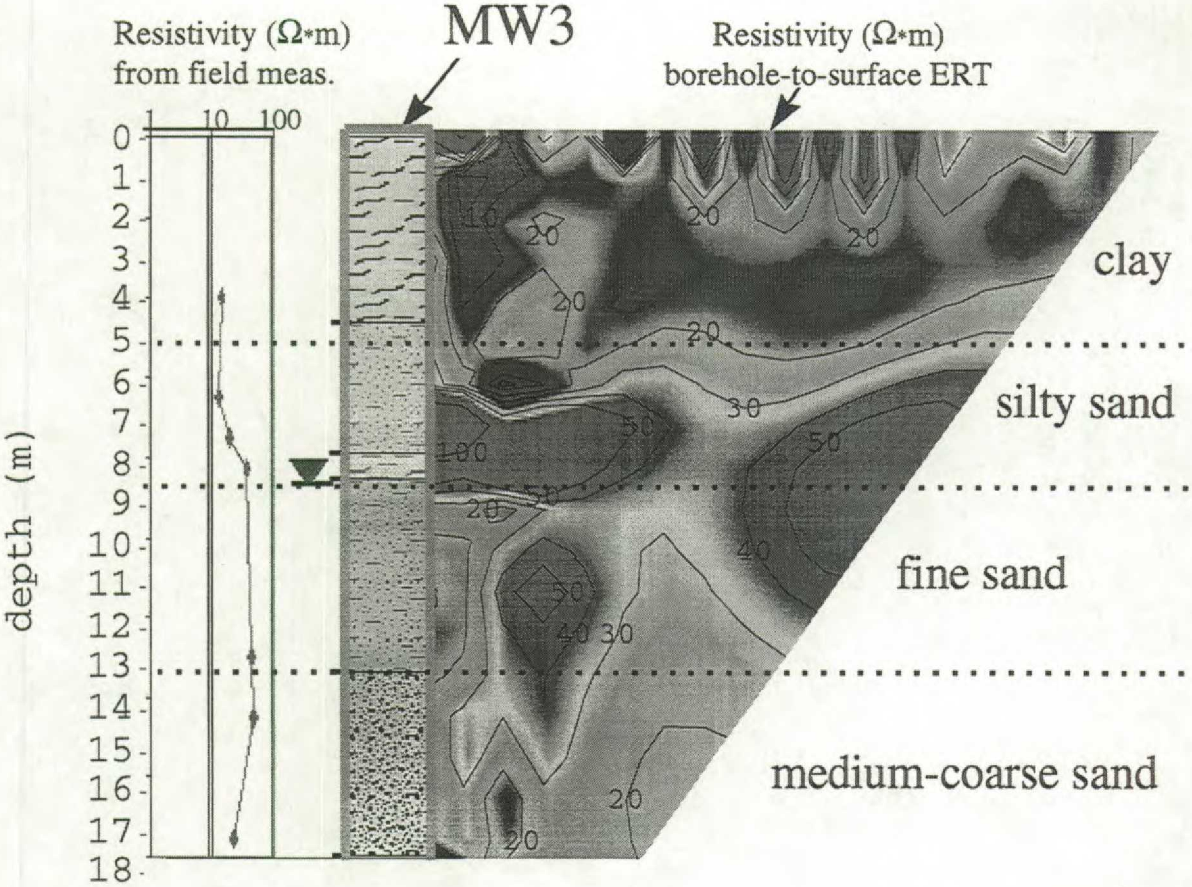

Figure 3 : Borehole-to-Surface ERT results (resistivity in Ohm*m) at well MW3

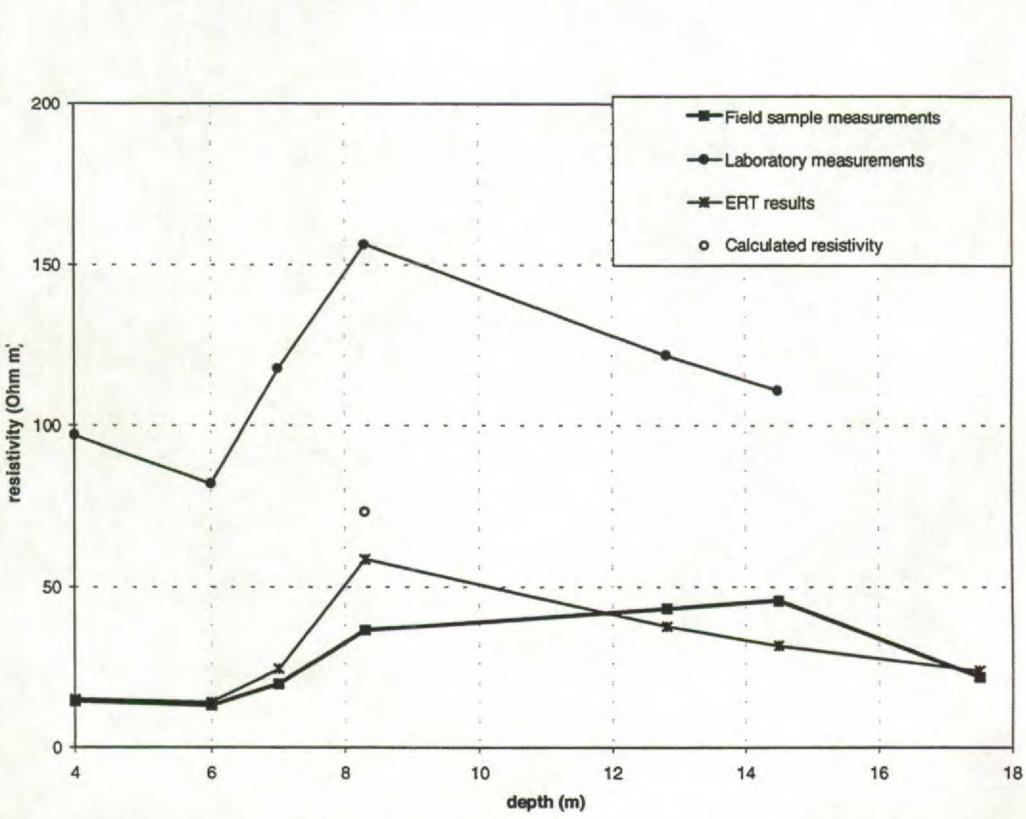

Figure 4 : Resistivities at well MW3 obtained from ERT, in-situ resistivity meter and laboratory measurements