ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/308035218

ERT and IPT Surveys to Check the Integrity of the Geomembrane in the Landfill of Bellolampo (Palermo, Italy)

Conference Paper · June 2016

DOI: 10.3997/2214-4609.201600799

CITATIONS
0

READS
30

4 authors, including:

Raffaele Martorana
Università degli Studi di Palermo

67 PUBLICATIONS **180** CITATIONS

SEE PROFILE

Patrizia Capizzi
Università degli Studi di Palermo

57 PUBLICATIONS **113** CITATIONS

SEE PROFILE

Dario Luzio
Università degli Studi di Palermo

99 PUBLICATIONS **403** CITATIONS

SEE PROFILE

All content following this page was uploaded by Raffaele Martorana on 12 November 2016.

The user has requested enhancement of the downloaded file. All in-text references underlined in blue are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

Tu SBT4 15

ERT and IPT Surveys to Check the Integrity of the Geomembrane in the Landfill of Bellolampo (Palermo, Italy)

R. Martorana (University of Palermo), P. Capizzi (University of Palermo), A. D'Alessandro* (Istituto Nazionale di Geofisica e Vulcanologia) & D. Luzio (University of Palermo)

SUMMARY

In landfills, changes in resistivity and chargeability can be related to the characteristics of the waste and they can be abrupt and considerable within short distances. These physical properties are function of generation, mobility and degree of saturation of the leachate, gas generation, compaction density and variability. These relationships mean that it can be possible to get an overall image of the quantity and characteristics of the waste from surface electrical measurements over the landfill. In this paper, we present and discuss the results of three electrical tomographies carried out in the landfill site of Bellolampo (Palermo, Italy). The main aim of these surveys was to check the integrity of the geomembrane. The application of the geoelectrical methods have allowed to obtain useful information to check the integrity of the geomembrane at the base of the new landfill built in the waste site of Bellolampo, unfortunately on fractured limestones and at high risk of pollution. The comparison between ERT and IPT, performed upstream, above and downstream of the landfill, allowed to identify the electrical properties of the rock, waste and leachate, and detect the possible presence of plumes of pollutant nearby and below the landfill.

Introduction

The environmental characterization of landfill sites suggests different objectives of investigation, including the geometric location and characterization of the sources of contamination, in terms of lateral extent, depth, contaminant leakage, waste type, (metal, hypersaline fluids, leachate, debris, etc.). Although most modern landfill sites are carefully selected and designed to minimize the risk of contamination of groundwater and bedrock, there are a large number of sites that have been developed before the dangers associated with the disposal waste were well understood. As a result, many places of older landfills have been chosen for convenience and proximity to the source of the waste, rather than environmental geological and engineering considerations. Unfortunately this is also the case of the landfills of Bellolampo, near Palermo, which were built on fractured limestones and dolomites.
A new landfill is still under construction but already partially filled with waste. Then it was evident the need to check the integrity of the protection HDPE geomembrane at the base of the landfill, and to avert the presence of any leaks of leachate in the underlying fractured sandstones.
The use of direct methods of investigation is not always applicable, due to the high cost and time and possible damage to the impermeable sheets to protect the landfill. The application of indirect geophysical methods can therefore be a viable alternative and, in fact, they are frequently cited in the literature. Among these, the most used are those of electrical resistivity (ERT) and induced polarization (IPT) tomography. In landfills, changes in resistivity and chargeability can be related to the characteristics of the waste and they can be abrupt and considerable within short distances. These physical properties are function of generation, mobility and degree of saturation of the leachate, gas generation, compaction density and variability. These relationships mean that it can be possible to get an overall image of the quantity and characteristics of the waste from surface electrical measurements over the landfill.
In recent years, various studies showed the use of ERT and IPT to characterize the structure of the waste landfill (Bernstone et al., 2000), to study the contamination of groundwater by leachate (Mondelli et al., 2007), to map the geometry and monitor the movement of the plume (Acworth and Jorstad, 2006), to evaluate the spatial and temporal variation of water content in the waste (Acworth and Jorstad, 2006 ; Mondelli et al., 2007). The leachate is a highly pollutant hypersaline fluid that is generated in landfills for a mineralization process of waste and degradation of organic matter. When the subsoil is subjected to an electric field, the high salt concentration of the leachate determines a sort of "battery effect" and a physical feature easily identified by the resistivity method. Yoon and Park (2001) showed that injecting highly conductive leachate into the top soil layer causes a resistivity decrease from 60% to 70%. Within the waste layer, other studies showed that the resistivity decreases from 30% to 60% (Guerin et al., 2004).

Method and instrumentation

Three electrical tomographies carried out in the landfill site of Bellolampo are presented and discussed. A preliminary resistivity tomography (T-T', not showed) was carried out parallel to the axis of the Karst valley of Piano Vurraine, NW of the landfill n.6, in a topographically higher area where it is clear a side passage between dolomies and limestones, in order to characterize the electrical resistivity of the successions outcropping in the area and to obtain useful information to estimate the degree of fracture and porosity. The second line (A-A') was carried out on sectors 1 and 2 of the landfill n. 6 (fig. 1) in order to detect the presence of the leakage in and out of the landfill. The third line (B-B'-B'') was carried out downstream and parallel to the eastern edges of the sectors 1 and 2 of the landfill, in order to identify any leachate plumes (fig. 1).
Measures has been acquired using a resistivity-meter MAE X612-EM+. This instrumentation allows multi-electrode resistivity profiles using contemporary 96 integrated electrodes. This feature allows a high measurement velocity, so allowing investigations before unfeasible. To use the full potential of the equipment is still necessary to optimize electrode sequences of acquisition, using arrays with physically separated dipoles, as the pole-dipole or dipole-dipole, or specifically designed multi-electrode arrays, as the *multiple gradient* array (Dahlin and Zhou, 2006).

Along the line T-T' 96 electrodes were placed, at regular distances of 10 m, for a total length of 950 m. To exploit the full potential of the multi-channel resistivity a sequence of dipole-dipole measures was used. The total sequence provided more than 3000 measurements of apparent resistivity.
Multiple gradient array was used to perform ERT and IPT along the line A-A', on sectors 1 and 2 of the landfill n. 6 of the landfill, to date in construction, but already partially filled. The measurements were acquired using 60 equally spaced electrodes of 5 m, for a total length of 295 m on the topographic surface. The electrode sequence used is based on the multiple gradient array with lengths of the potential dipoles a = 5m, a = 10m, a = 15m. The current dipoles chosen had lengths equal to 1, 1/2, 1/3, 1/4, 1/5, 1/6 of the maximum line length (300m) and with a step between each current dipole equal to half the length of the dipole current itself (Martorana et al., 2015). Accordingly, 2805 measures have been carried out.
Tomography B-B'-B" was carried out downstream and parallel to the eastern edges of the sectors 1 and 2 of the landfill. Even in this case we used the multiple gradient sequence above described. The measurements were performed using 58 electrodes, spacing 5 m, for a total length of 285 m.
For each measure at least 6 repetitions were estimated, in order to obtain a S/N adequately high and to estimate the standard deviation. Nevertheless, the high heterogeneity of the waste, together with the high resistivity of the rocks, caused the presence of several outliers. Thus only measures that showed a standard deviation less than 10% was considered in the inversion. The filtered data were processed and inverted with RES2DINV software, using an L_1-norm least squares algorithm, smoothness constrained (Wolke and Schwetlick, 1988).

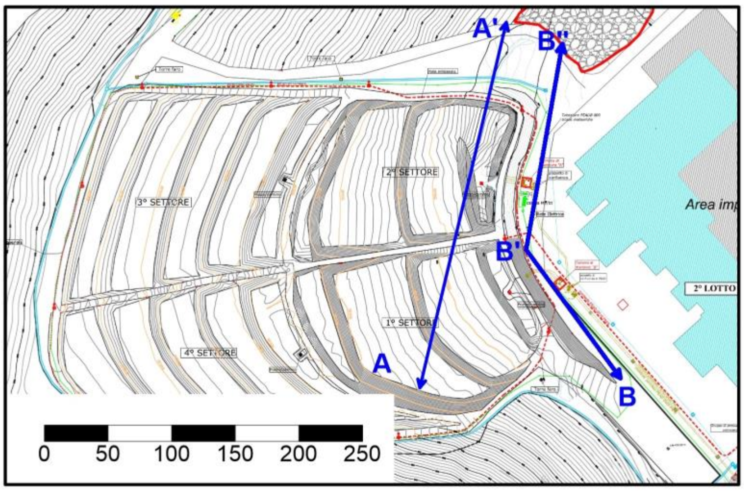

***Figure 1** Map of the landfill n. 6 of Bellolampo (Palermo) showing the ERT and IPT lines A-a' and B-B'-B''.*

Results

For the T-T' tomography, the high heterogeneity of the near surface layer, together with the high resistivity of the outcropping rocks, caused the presence of numerous outliers. After their elimination 2132 measures were selected for the inversion. Results show very high resistivity values of the formations, order of 10^3 -10^4 Ωm. There is a lateral variation of resistivity at the hypothetical side contact between the Triassic dolomites and the Jurassic limestones. Moreover, a near surface altered layer, with heterogeneous values of resistivity, is evident in the right part of the section. The results show a good correspondence between the disposal of rocky formations detected in surface and the resistivity tomography.
The dataset of the line A-A' presented a median standard deviation equal to 2.4%. However, even in this case the high heterogeneity of the material investigated and the high resistivity of the rock formations caused the presence of several outliers. After eliminating all data with standard deviation greater than 10%, 1937 measures resulted with a median standard deviation of 0.9%. For the inversion, the implementation suggested by Ellis and Oldenburg (1994) was used to include a priori information consisting of the known position of the geomembrane at the bottom of the landfill, so as

to force the vertical resistivity gradient to fit this surface. The results (Fig. 2) show a misfit between measured and calculated equal to 13%. Electrical resistivity and induced polarization tomographies reproduce quite well the geometry of the landfill bottom and the position of the leachate, identified by very low resistivity values and high chargeability, corresponding to the lower regions of the landfill.
It is emphasized that the protection cloth of high-density polyethylene (HDPE) in the landfill bottom, when it is healthy, does not allow the passage of electric current, preventing to investigate the resistivity of the bottom rocks. Therefore, if the conditions of integrity of the HDPE protection liner are satisfied, the model below the cloth will show high and substantially homogeneous values of electrical resistivity, independently of the actual values of resistivity of the rocks. To this regard it is noted that the resistivity model has high and substantially homogeneous values below the bottom geomembrane, with the exception of two zones: the first one at about 100-105 m from the beginning of the profile (point A), between the 1st and the 2nd sector; the other one in the 2nd sector, approximately 210-230 m from the point A. Whereas in correspondence of the first zone the chargeability (Fig. 2, bottom) does not show significant values this area is considered unlikely affected by the presence of leachate. At the second zone the chargeability instead shows values greater than 50 ms, potentially compatible with presence of leachate. However, this area is located at the edge of the 2nd sector, very close to the end of the geomembrane and to the clay layer of protection of the tank bottom, which can have resistivity and chargeability values compatible with those obtained. The zone underlying the geomembrane, starting from about 165 m from the point A, shows inhomogeneous resistivity values, probably due to the arrays of the current dipoles, which in the final part of the line have been placed beyond the limit of 2nd sector. This arrays probably allowed current to partially flow below the geomembrane and to investigate the underlying materials in this zone of the tomography.

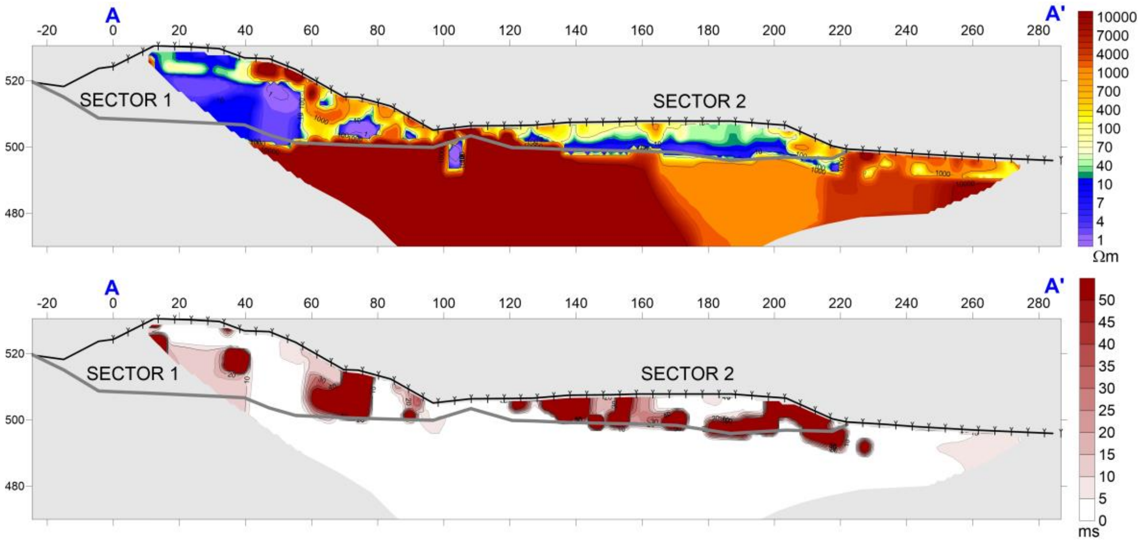

Figure 2 *Results of electrical tomography along the line A-A': top) Resistivity section; bottom) chargeability section. Grey line indicates the position of the geomembrane.*

The dataset of line B-B'-B'' was filtered, eliminating all outliers with a standard deviation higher than 10%. 2396 measures resulted with a median standard deviation of 0.7%. The inverted electrical resistivity model shows a RMS misfit equal to 8.8%. The results of ERT and IPT are shown in Fig. 3. Electrical resistivity shows high values compatible with limestone lithologies outcropping in that area. The relative lateral heterogeneity of electrical resistivity (Fig. 3, top) is likeminded by the variations of fracturing and porosity of limestones, which cannot be highlighted by the chargeability (Fig. 3, bottom). There are also some near surface anomalies of higher resistivity, in correspondence of the control rooms and the HDPE collectors, located in Fig. 1. A small conductive area (resistivity less than 60 Ωm) is highlighted, characterized by chargeability values higher than 40 ms, located at about 230-240 m from the point B (Fig. 3, bottom). These values are compatible with the possible presence of leachate, which, however, is unlikely because of the size and shape of the highlighted geometry.

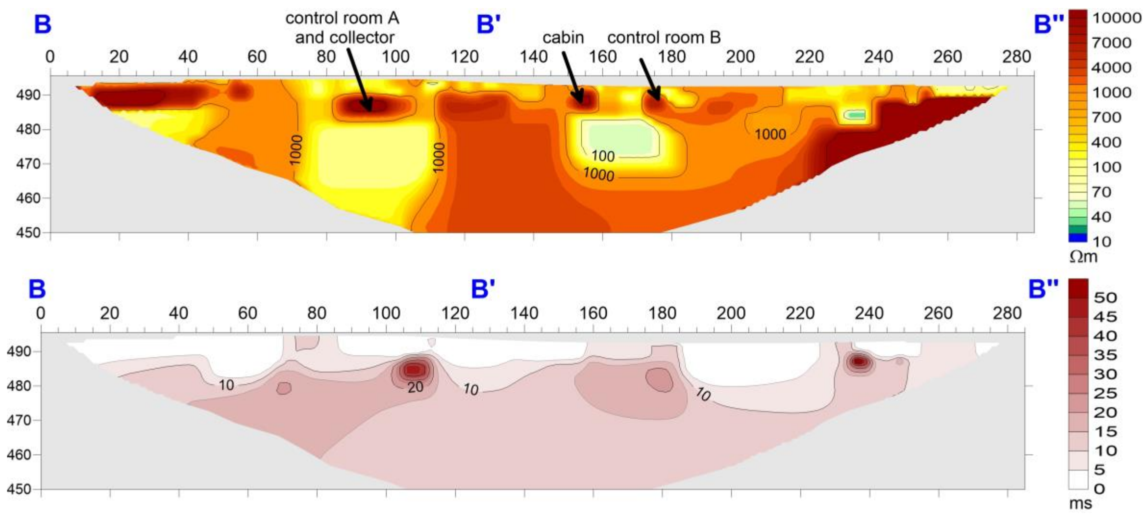

Figure 3 *Results of electrical tomography along the line B-B'-B'': top) Resistivity section; bottom) chargeability section.*

Conclusions

The application of the geoelectrical methods have allowed to obtain useful information to check the integrity of the geomembrane at the base of the new landfill built in the waste site of Bellolampo, unfortunately on fractured limestones and at high risk of pollution. The comparison between ERT and IPT, performed upstream, above and downstream of the landfill, allowed to identify the electrical properties of the rock, waste and leachate, and detect the possible presence of plumes of pollutant nearby and below the landfill.

References

Acworth, R.I. and Jorstad, L.B. [2006] Integration of multichannel piezometry and electrical tomography to better define chemical heterogeneity in a landfill leachate plume within a sand aquifer. *Journal of Contaminant Hydrology*, **83**, 200-220.

Bernstone, C., Dahlin, T., Ohlsson, T. and Hogland, W. [2000] DC-resistivity mapping of internal landfill structures: two pre-excavation surveys, *Environmental Geology*, **39**, 360–371.

Dahlin, T. and Zhou B. [2006] Multiple-gradient array measurements for multichannel 2D resistivity imaging. Near Surface Geophysics, **4** (2), 113–123.

Ellis, R.G. and Oldenburg, D.W. [1994] Applied geophysical inversion. *Geophysical Journal International*, **116**, 5-11.

Guérin, R., Munoz, M.L., Aran, C., Lapperrelle, C., Hidra, M., Drouart, E. and Grellier, S. [2004] Leachate recirculation: moisture content assessment by means of a geophysical technique. *Waste Management*. **24**, 8, 785–794, DOI: 10.1016/j.wasman.2004.03.010.

Martorana, R., Capizzi, P., D'Alessandro, A. and Luzio, D. [2015] Comparison of different acquisition patterns for 2D tomographic resistivity surveys. *Near Surface Geoscience 2015 – 21st European Meeting of Environmental and Engineering Geophysics*. Turin, Italy, 6-10 September 2015, Mo 21P1 08, DOI: 10.3997/2214-4609.201413684.

Mondelli, G., Giacheti, H.L., Boscov, M.E.G., Elis, V.R. and Hamada, J. [2007] Geoenvironmental site investigation using different techniques in a municipal solid waste disposal site in Brazil. *Environmental Geology*, **52**, 871-887.

Wolke, R. and Schwetlick, H. [1988] Iteratively reweighted least squares algorithms, convergence analysis, and numerical comparisons. *SIAM Journal of Scientific and Statistical Computations*, **9**, 907-921.

Yoon, G.L. and Park, J.B. [2001] Sensitivity of leachate and fine contents on electrical resistivity variations of sandy soils. *Journal of Hazardous Material*. **84**, 2–3, 147–161, DOI: 10.1016/S0304-3894(01)00197-2.