A geophysical toolbox for imaging and characterization of a landfill

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INTRODUCTION

Leachate and gas are a product of biochemical reactions occurring inside the landfill. Treatment technologies (e.g., recirculation of leachate) are developed to reduce the production of leachate. Imaging the location of the wet and gas pockets inside the landfill can help improve the treatment technologies. Wet pockets occur inside the landfill due to the presence of high-density areas that act as obstructions to the fluid flow (Figure 1). We propose the utilization of geophysical methods – seismic and electrical – to image and characterize the landfill's structure. In detail, we use the seismic method to: (a) image the high-density areas (scatterers); (b) obtain a density distribution of the landfill; (c) locate gas and wet pockets. We use the electrical resistivity method to image low-resistivity areas that indicate wet zones. The electrical resistivity method when used alone is prone to artifacts and uncertainties (Jolly et al., 2009). A combination of the two methods has proven to improve the understanding of the landfill's subsurface (Konstantaki et al., 2015a). In the following, we show results obtained at two different landfill locations in the Netherlands (Wieringermeer and Twence).

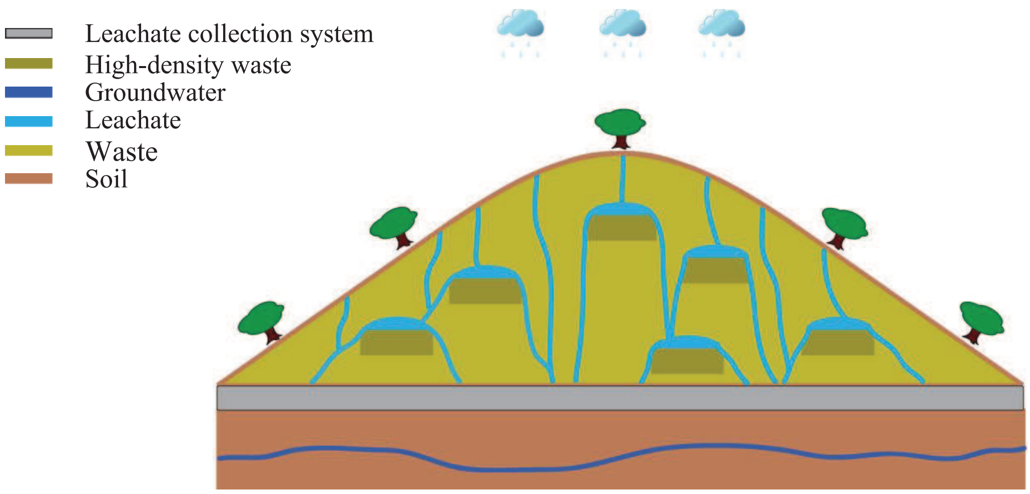

Fig. 1: Cartoon of a landfill's subsurface. High-density areas act as obstructions to the fluid flow and thus create wet pockets.

THE TOOLBOX

The processing of seismic data obtained at a landfill site is challenging (Green et al., 1999). Konstantaki et al. (2015a) developed processing steps for such seismic data. One of the outputs of the processed seismic data is a velocity-distribution map of the shear (S) wave velocity map in Figure 2a, while in Figure 2b we show the result from the electrical resistivity tomography (ERT). Figure 2 shows the location of wet pockets after interpretation of both results (see lines and capital letters). For example, line A shows a contrast in the velocities (Figure 2a), indicating the start of a higher-density area. In Figure 2b above line A a lower resistivity area is present indicating a wet pocket.

In a modeling study, we have shown that seismic interferometry (SI) can image the high-density areas better than the conventional seismic reflection survey method (CRSS) (Konstantaki et al., 2013a). We applied the method to field data from Wieringermeer landfill (Konstantaki et al., 2015b). In Figure 3a, we show an image of the landfill obtained from CRSS, while in Figure 3b we show the image obtained after application of SI to the CRSS field data. More scatterers are interpretable in the SI image and their location is better defined.

In a second field study, we constructed S- , as well as compression- (P) wave seismic maps. The P- and S-wave velocity ratio (Vp/Vs) can be used to interpret gas (e.g., Westbrook et al., 2008) or water (e.g., Konstantaki et al., 2013b) zones in the subsurface. Figure 4a shows the obtained Vp/Vs ratio for the landfill's subsurface. Lower ratio is an indication for presence of gas pockets, while higher ratio is an indication for water pockets. Finally, Figure 4b shows the density distribution we determined from the seismic data. It is obtained using an empirical relationship between S-wave velocities and unit weight, specifically valid for landfills (Choudhury and Savoikar, 2009).

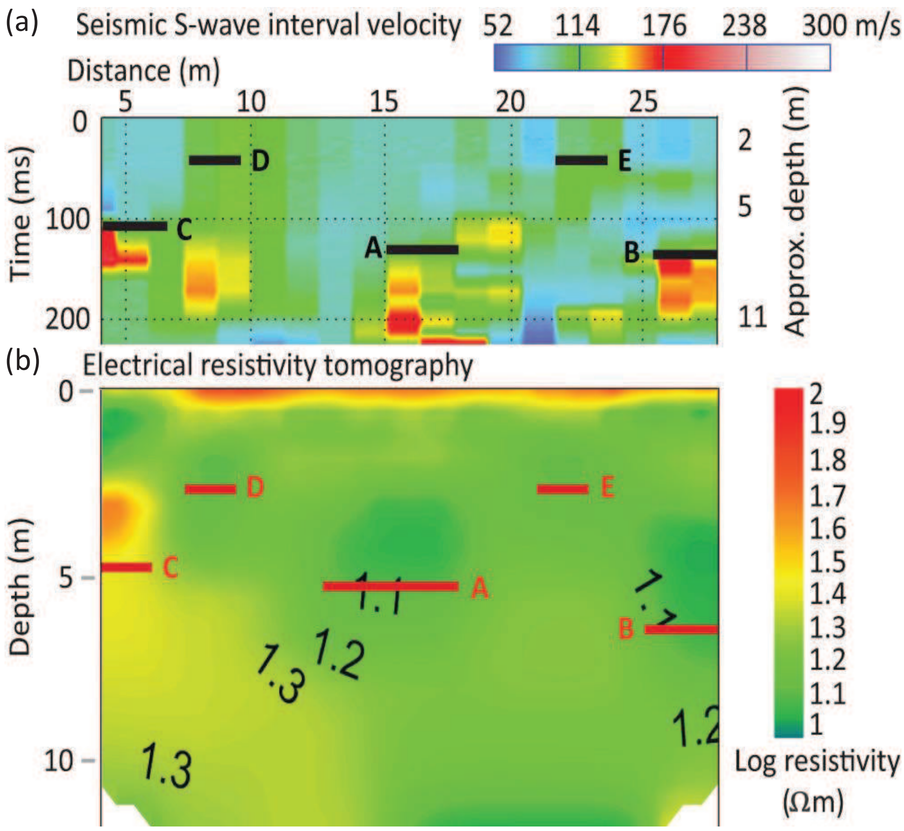

Fig. 2: (a) Velocity field obtained from S-wave measurements, (b) electrical resistivity tomography (ERT). The letters and lines indicate the locations of high-density areas that act as obstruction to the fluid flow. Adjusted from Konstantaki et al. (2015a).

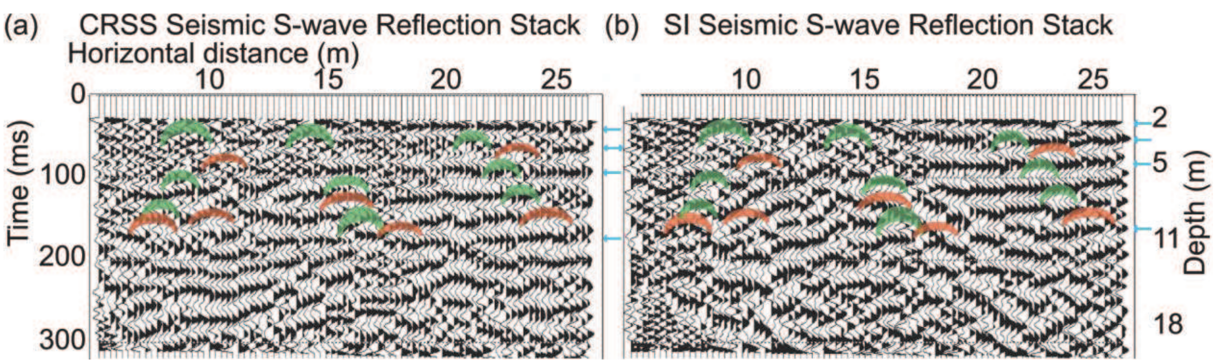

Fig. 3: Stacked image of the landfill's subsurface using the (a) conventional reflection seismic survey (CRSS) method and (b) seismic interferometry (SI). Green hyperbolas indicate scatterers (high-density areas) that are interpreted on the SI data, whereas red hyperbolas - the ones interpreted on the CRSS data. The blue arrows point to reflectors. Adjusted from Konstantaki et al. (2015b).

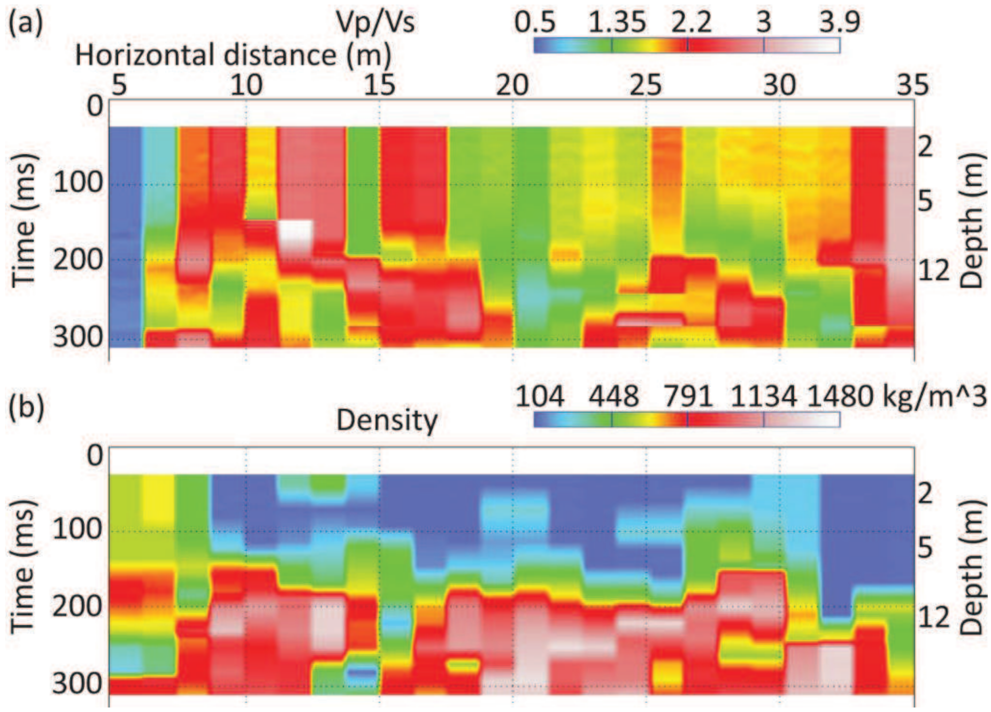

Fig. 4: (a) P- and S-wave velocity ratio distribution, (b) density distribution.

CONCLUSIONS

We proposed a geophysical toolbox for the characterization of landfills. The toolbox consists of seismic and electrical methods. With their help, we showed that we can image the landfill's structure, extract its density distribution, and interpret wet and gas pockets.

REFERENCES

Choudhury, D. and Savoikar, P. (2009) "Simplified method to characterize municipal solid waste properties under seismic conditions", *Waste Management*, Vol. 29, 924-933.

Green, A. G., Lanz, E. and Maurer H. (1999) "A template for geophysical investigations for small landfills", *The Leading Edge*, Vol. 18, 248–254.

Konstantaki, L.A., Draganov, D., Ghose, R. and Heimovaara, T. (2013a) "Imaging scatterers in landfills using seismic interferometry", *Geophysics*, Vol.78, 1-10.

Konstantaki, L.A., Carpentier, S., Garofalo, F., Bergamo, P. and Socco, L.V. (2013b) "Determining hydrological and soil mechanical parameteres from multichannel surface-wave analysis across the Alpine Fault at Inchbonnie, New Zealand", *Near Surface Geophysics*, Vol.11, 435-448.

Konstantaki, L.A., Ghose, R., Draganov, D., Diaferia, G. and Heimovaara, T. (2015a) "Characterization of a heterogeneous landfill using seismic and electrical resisivity data", *Geophysics*, Vol.80, EN13-EN25.

Konstantaki, L.A., Draganov, D., Ghose, R. and Heimovaara, T. (2015b) "Seismic interferometry as a tool for improved imaging of the heterogeneities in the body of a landfill", *Journal of Applied Geophysics*, submitted.

Westbrook, G.K., Chand, S., Rossi, G., Long, C., Bünz, S., Camerlenghi, A., Carcione, J.M., Dean S., Foucher, J.-P., Flueh, E., Gei, D., Haacke, R.R., Madrussani, G., Mienert, J, Minshull, T.A., Nouzé, H., Peacock, S., Reston, T.J., Vanneste, M. and Zillmer, M.. (2008) "Estimation of gas hydrate concentration from multi-component seismic data at sites on the continental margins of NW Svalbard and the Storegga region of Norway", *Marine and Petroleum Geology*, V. 25, 744-758.

Jolly J. M., Barker R. D., and Beaven R. P. (2011) "Resolution of electrical imaging o fluid movement in landfills", *Proceedings of the ICE – Waste and Resource Management*, V. 164, 79-96.