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Landfill investigation using geophysical methods for an improved characterization of the landfill geometry and for assessing microbiological activity

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Introduction

The material deposited in the investigated landfill consists of municipal solid waste (MSW – ca. 66 %), construction and demolition waste (CDW – ca. 16 %) as well as excavated soil (ca. 18 %). Flores Orozco et al. (2020) showed that the induced polarization (IP) imaging is well-suited method to distinguish between different waste types and delineate biogeochemical active zones (Figure 1). Such active zones (hot-spots) refer to wet MSW where high rates of biogeochemical activity takes place resulting in the formation of CO_2. However, the IP method requires that electrodes (steel stakes) are hammered into the surface, which could breach near surface membrane (intended to confine produced gases). Hence, we investigate here the applicability of contactless transient electromagnetic (TEM) soundings to permit similar landfill investigations, namely, to delineate the geometry of the landfill with high resolution, and to map active zones.

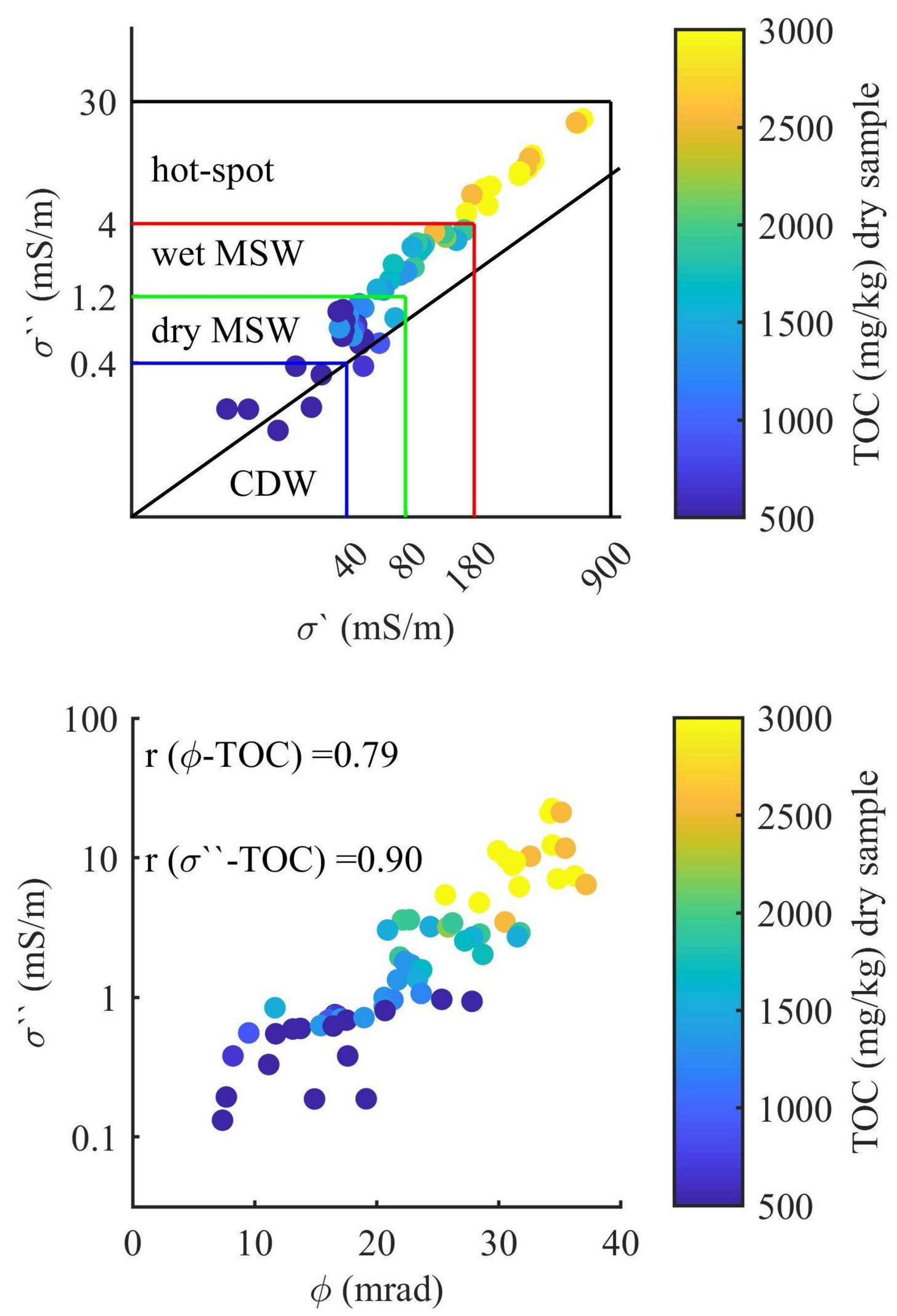


Figure 1:
The correlation between the electrical parameters (σ', σ'', and ϕ retrieved from the induced polarization (IP) imaging results) and the biogeochemical information (expressed in terms of the total organic content (TOC) in leachate from solid waste samples) clearly shows the capability of the IP method to delineate between waste type and to distinguish biochemically active zones. Figure from Flores Orozco et al. (2020).

Material and Method

We present data collected at a single profile, where spectral induced polarization (SIP) measurements were collected using a DAS-1, electrical impedance tomography System (Multi Phase Technologies, LLC) . We deployed 64 electrodes with a separation of 1 m and shielded coaxial cable developed at the TU Wien to minimize the contamination of the SIP data due to electromagnetic coupling. Data were obtained from 0.1 Hz to 225 Hz using 14 discrete frequencies. SIP measurements at each independent frequency were inverted with CRTomo (Kemna, 2000).

At the same profile, we measured TEM soundings with the TEM-FAST 48 system (AEMR research) using a 12.5 m square loop in a single loop configuration. We used 4 A of direct current to create the primary field and measured the secondary field in 32 time windows ranging from 4.1 µs to 1024 µs. The positions of the TEM soundings in relation to the IP profile are shown in Figure 3. Analysis of the data revealed TEM soundings with good quality in the time range between 10 and 200 µs (Figure 2). Hence, readings within such range were further inverted using the commercial software ZONDTEM1D (Zond Software, Alex Kaminsky) to solve for the vertical variation of the electrical resistivity (ρ).

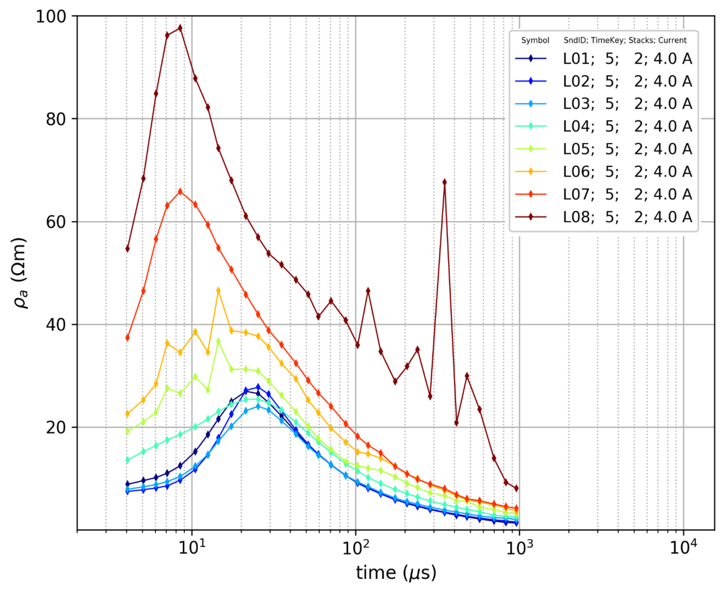


Figure 2:
Transient electromagnetic (TEM) data visualization in terms of the apparent resistivity as provided by the TEM-FAST 48 system.

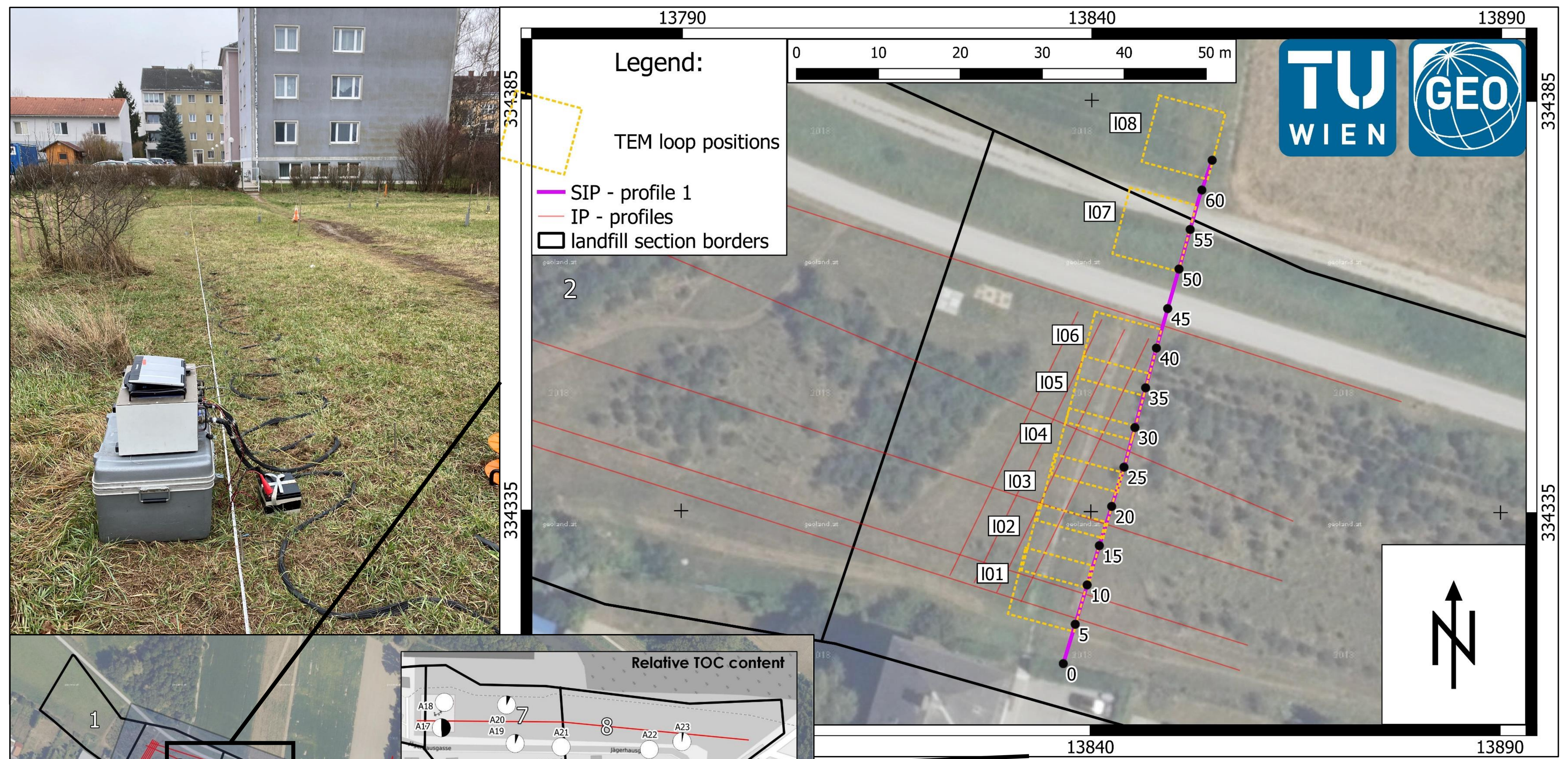


Figure 3:
Overview of the TEM measurement setup. The profile starts in the south and the border of the dam in the north. The picture to the left shows the DAS-1 and the profile in southern direction.

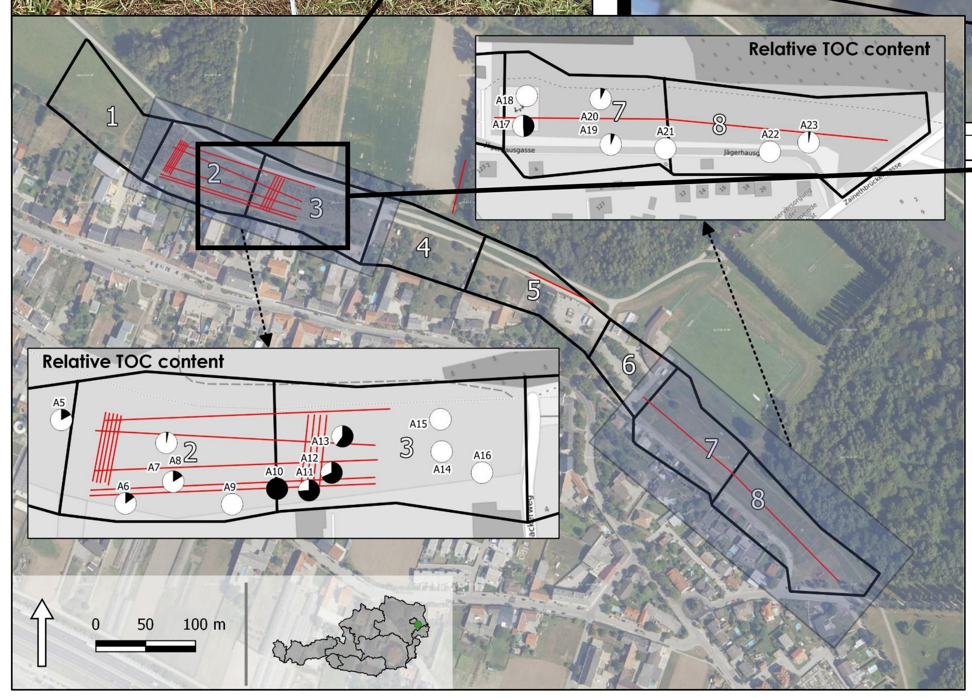


Figure 4:
A comprehensive overview of the Heferlbach landfill, which is located close to Schwechat in Austria. The red lines indicate the positions of the 17 IP profiles collected for the study of Flores Orozco et. al (2020). Further details on the aeration system and the landfill itself can be found in the study of Brandstätter et al. (2020) and the references therein. The small circular diagrams represent the amount of TOC found at those locations (high TOC – blacker circle)

Results and Discussion

The comparison of the conductivity (σ = 1/ρ) obtained by TEM and IP methods clearly shows that the TEM method resolves for similar subsurface models of the electrical conductivity. In particular, the images of the electrical conductivity solved for the inversion of SIP data (results presented for data collected at 1 Hz in Figure 6) and for the TEM soundings reveal a clear anomaly characterized by high conductivity values. This anomaly corresponds to high total organic carbon (TOC) measured in leachate of solid waste (as illustrated in Figure 4). As demonstrated in Flores Orozco et al. (2020), such anomalies also correspond to high polarization anomalies (ϕ > 30 mrad in Figure 5) evidencing a biogeochemical active zone. Furthermore, the areas with a conductivity below 25 mS/m of the subsurface model represent the underlying geology (along the entire profile and below 150 m) as well as dry MSW and CDW (between 30 and 40 m profile distance – above 150 m).

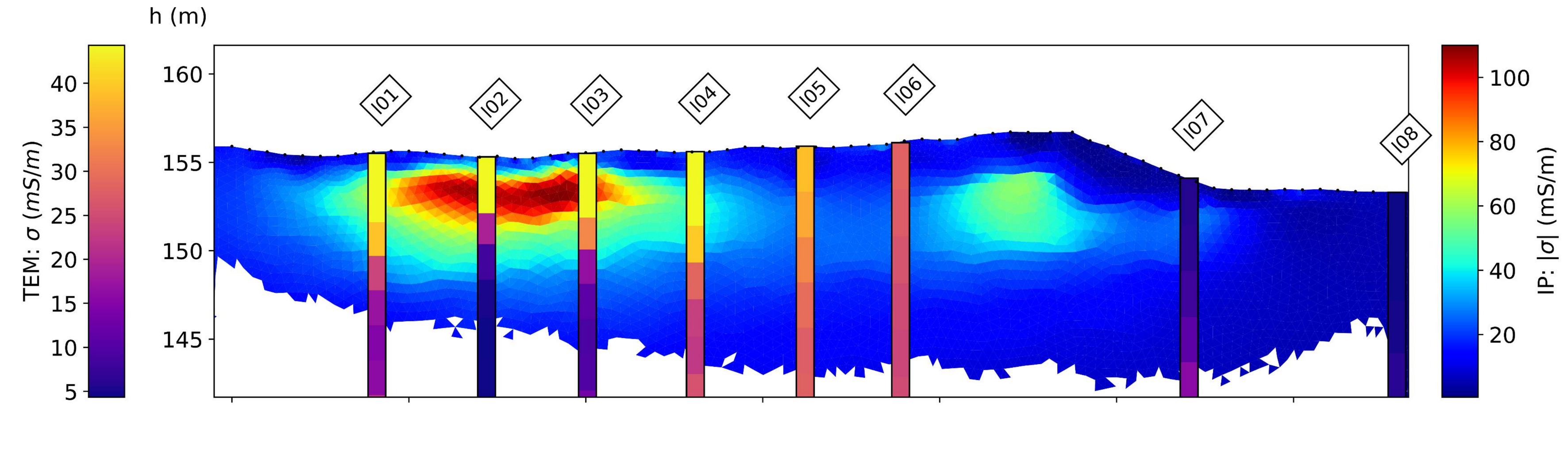
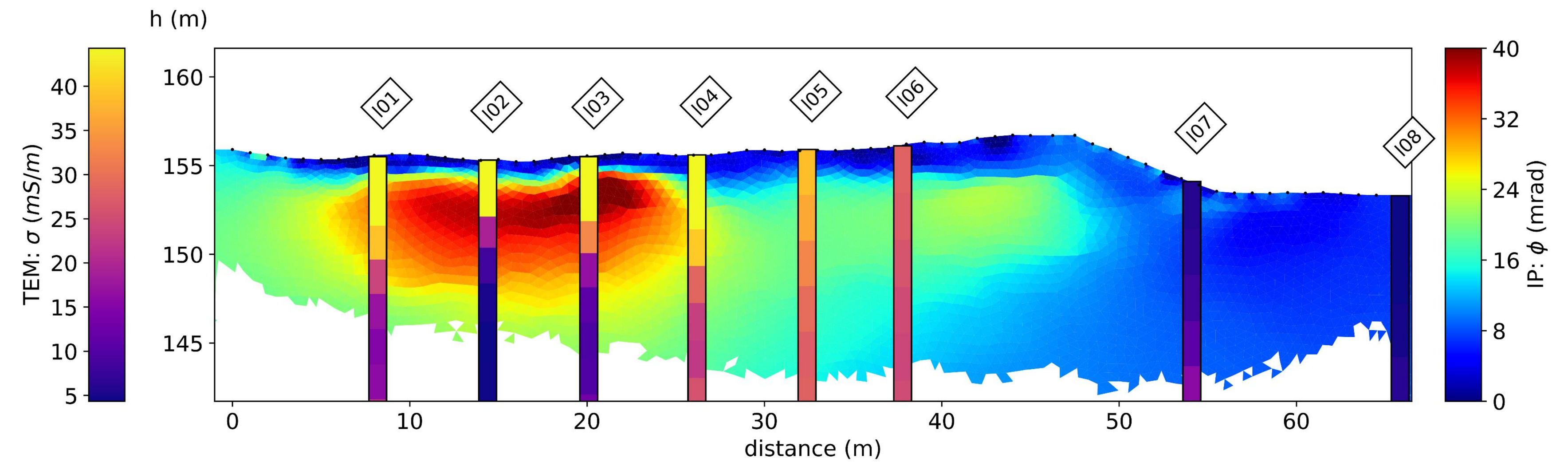


Figure 5:
Comparison of 1D sounding models obtained by the TEM method by imposing them on top of the magnitude (|σ|) and phase (ϕ) of complex conductivity measured using the IP method.



Conclusion and Outlook

- TEM method capable of obtaining similar information as the IP method.
- Lateral resolution is limited compared to IP, but the vertical resolution might be useful to constrain and further improve the IP imaging results

Future work will focus on:
- Assessing the frequency dependence of the IP method
- IP effect in TEM measurements

References

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