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Landfill characterization by multi-method geophysical investigation: the case study of Leppe (Germany)

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LIÈGE université | UEE Urban & Environmental Engineering

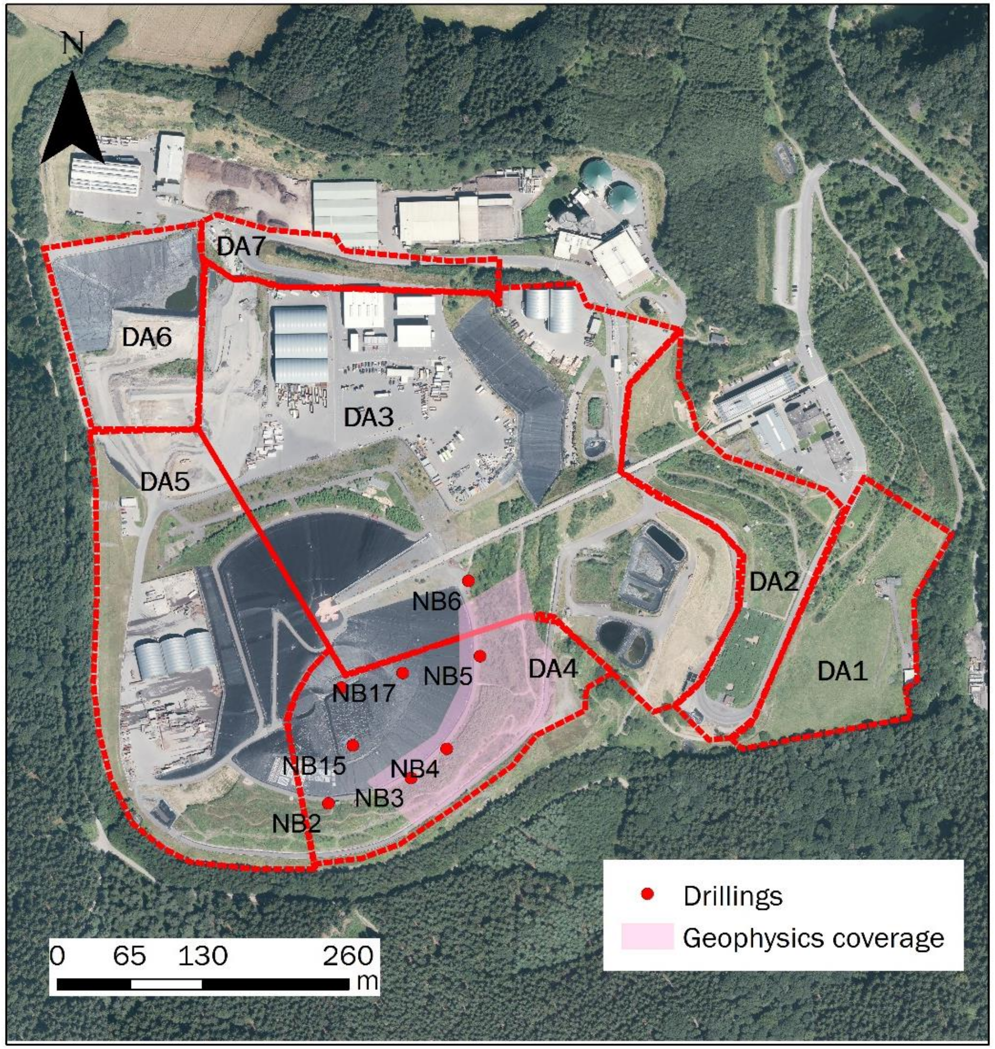
BAV Bergischer Abfallwirtschaftsverband

:metabolon

Summary

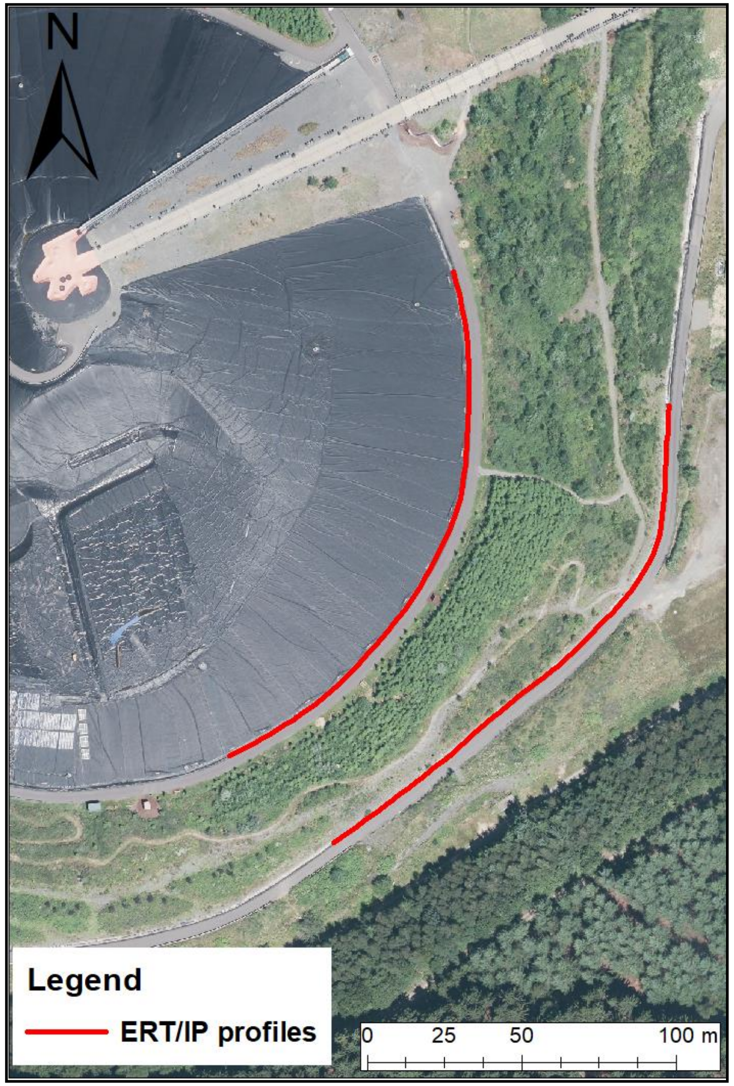
Methods	Objectives	Results
Electrical Resistivity Tomography (ERT) & Induced polarization (IP)	Waste-type distinctions, investigation in leachate content, detection of metallic scraps or zones of higher organic content	Delineation of different wastes, insufficient sensitivity, promising results in the estimation of waste types and volumes for the IP
Multichannel Analysis of Surface Waves (MASW)	Indication on the layers' composition and transition with the host material	Detection of three distinctive layers (ash, municipal solid waste, geological host)
Horizontal to vertical noise spectral ratio (HVNSR)	Estimation of the waste thickness	Good agreement between the estimated bottom layer and the topography known before landfilling

LEPPE LANDFILL DESCRIPTION



- From 1892 to 2004 : Municipal solid waste (MSW) deposit in areas DA1, DA2, DA3 and DA4, overlaying a geological host mainly composed of sandstone, siltstone and mudstone
- Since 2005, only ash MSW incineration deposited in DA4 and DA5 on top of the prior MSW and in mono-deposition in DA6
- A landfill capping in DA1 to DA5 enables the extraction of biogas to a rate of about 450 – 500 m^3/h
- Drilling campaigns, in 2017 and 2018, in zones DA3, DA4 and DA5
- Due to logistical and infrastructure constraints (*i.e.* complete cone built from incineration ash, geomembrane), the geophysical survey focused on the DA4 zone, underneath the cone

ERT/IP



❑ **Objectives :**

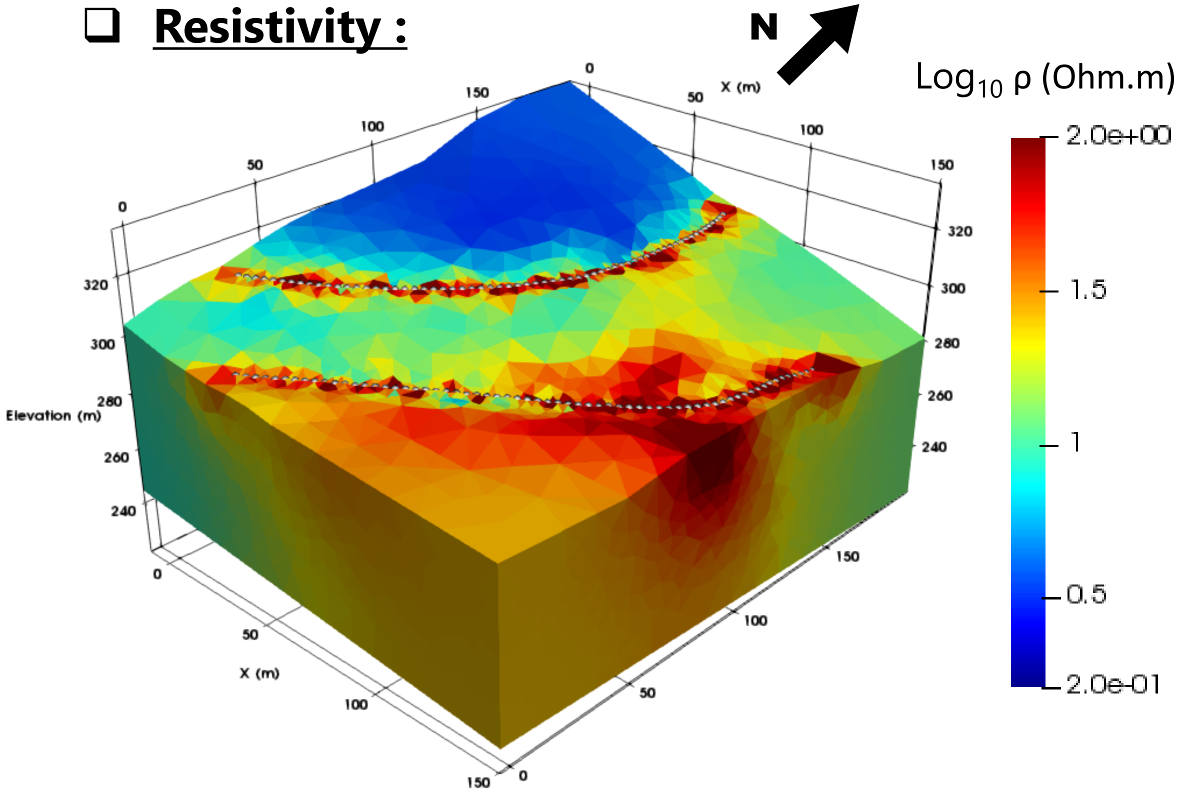
- Resistivity distribution : Discrimination of different waste types and investigation of changes in leachate content
- Chargeability distribution : Detection of metallic scraps or zones of higher organic content

❑ **Measurements :**

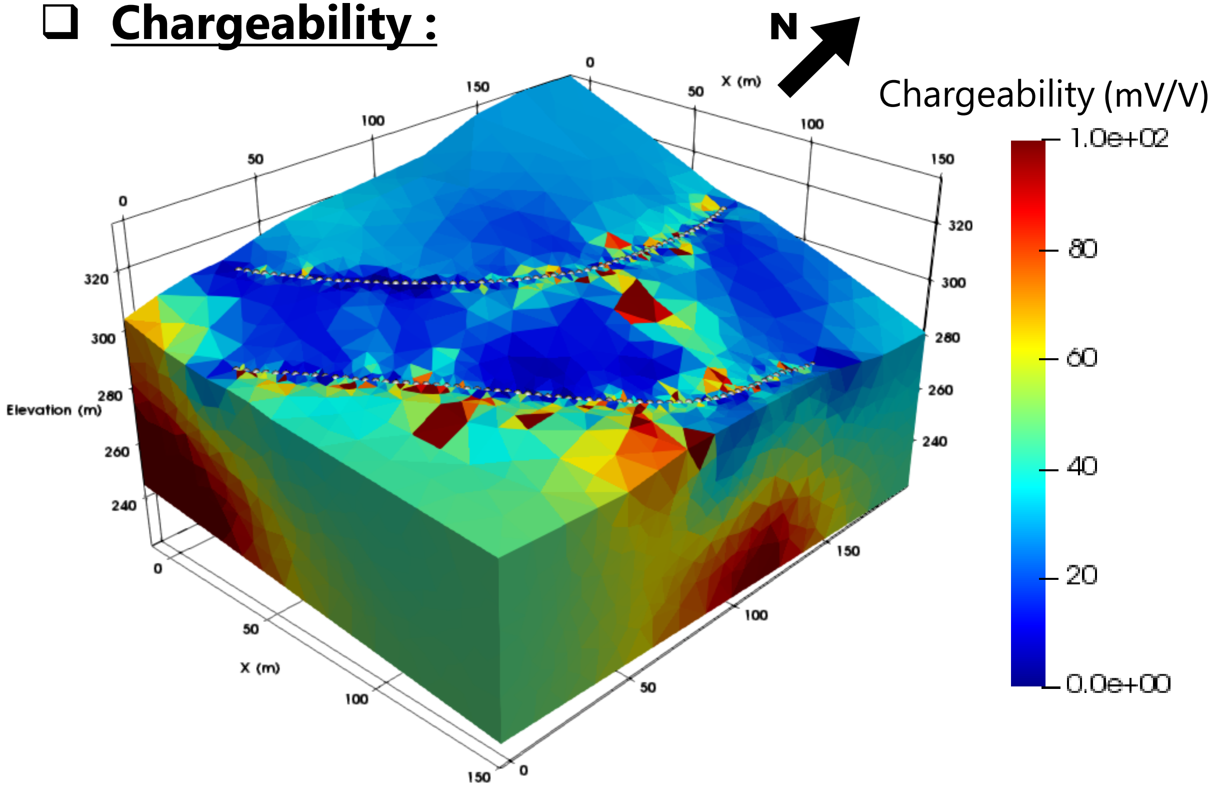
- Two nearly parallel profiles, spaced of 55 m at the bottom part of the landfill cone, each containing 64 stainless electrodes with a spacing of 3 m
- Data acquisition with a combination of a dipole-dipole array (n factor = 6), a gradient array (s factor = 8) (Dahlin & Zhou, 2006) and a bipole-bipole array
- Inline and crossline measurements
- Repetition of measurements to estimate the repetition error and collection of reciprocal measurements at each profile to assess of data quality

ERT/IP 3D MODELS

Resistivity :



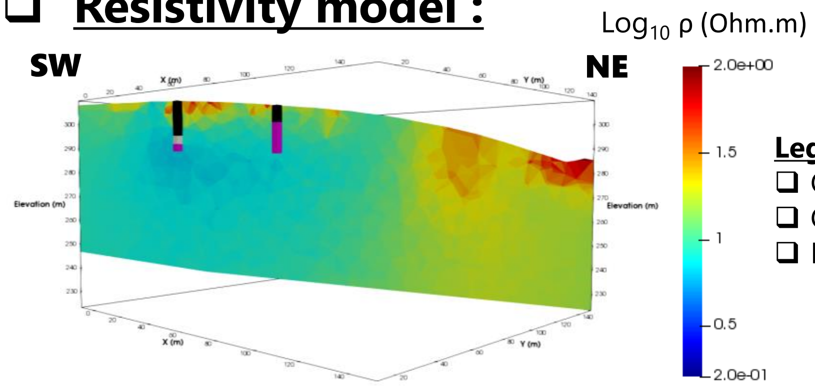
Chargeability :



- Surface artefacts close to the electrode positions
- Very low global electrical resistivity observed (98.9% <100 Ohm.m)
- Lowest values in the western part of the model (<10 Ohm.m)
- Acute contrast in the chargeability model

ERT/IP 2D SLICE CUT

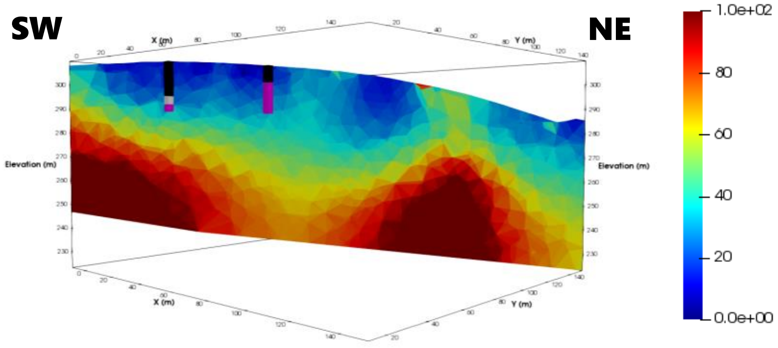
❑ Resistivity model :



Legend:
- ❑ Cover material
- ❑ Construction
- ❑ Municipal solid waste

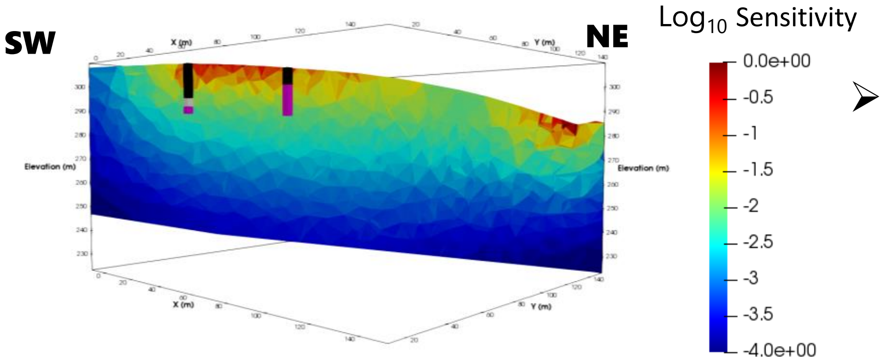
- ➢ Exhibits a lateral contrast
- ➢ The lower resistivity zones may be related, in general, to a higher content in ash and household wastes
- ➢ The higher resistivity zones may correspond to a higher content in inert materials and to the geological host
- ➢ The vertical resistivity contrast does not allow the base of the landfill to be inferred

❑ Chargeability model :



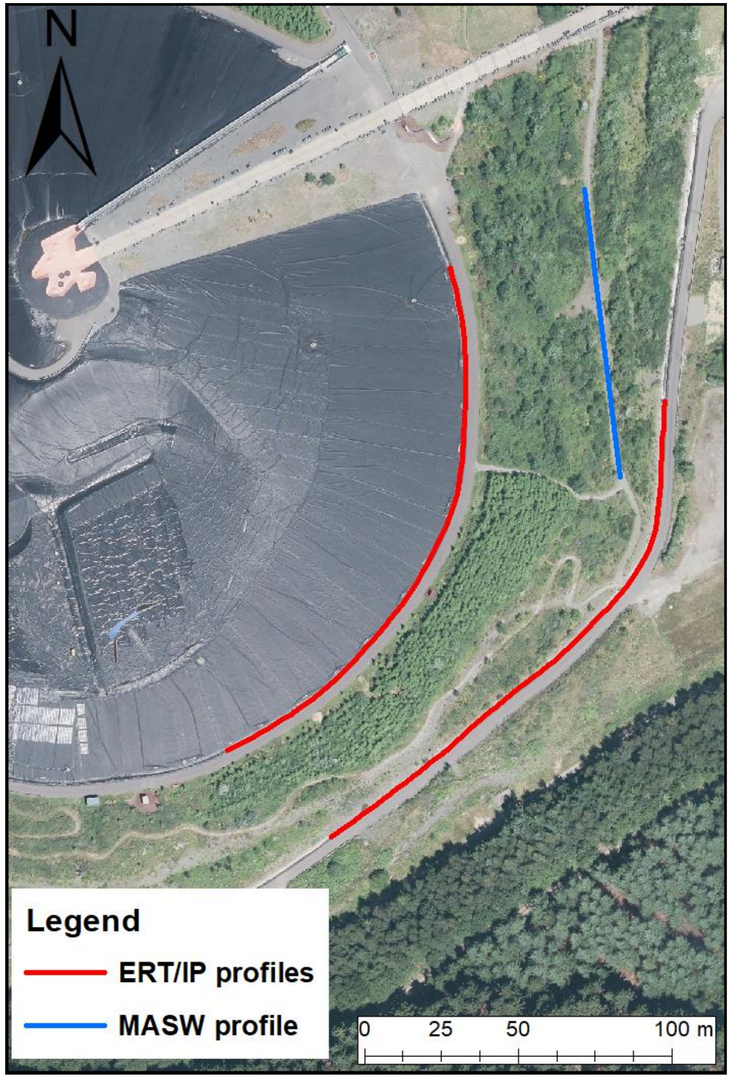
- ➢ Shows a more pronounced variability with depth
- ➢ The low chargeability may characterize the inert waste
- ➢ The medium chargeability may correspond to the household waste
- ➢ The high chargeability might be related to the geological host

❑ Sensitivity model :



- ➢ In zones of low sensitivity, the contrast is attenuated and does not allow to accurately image the interface

MASW



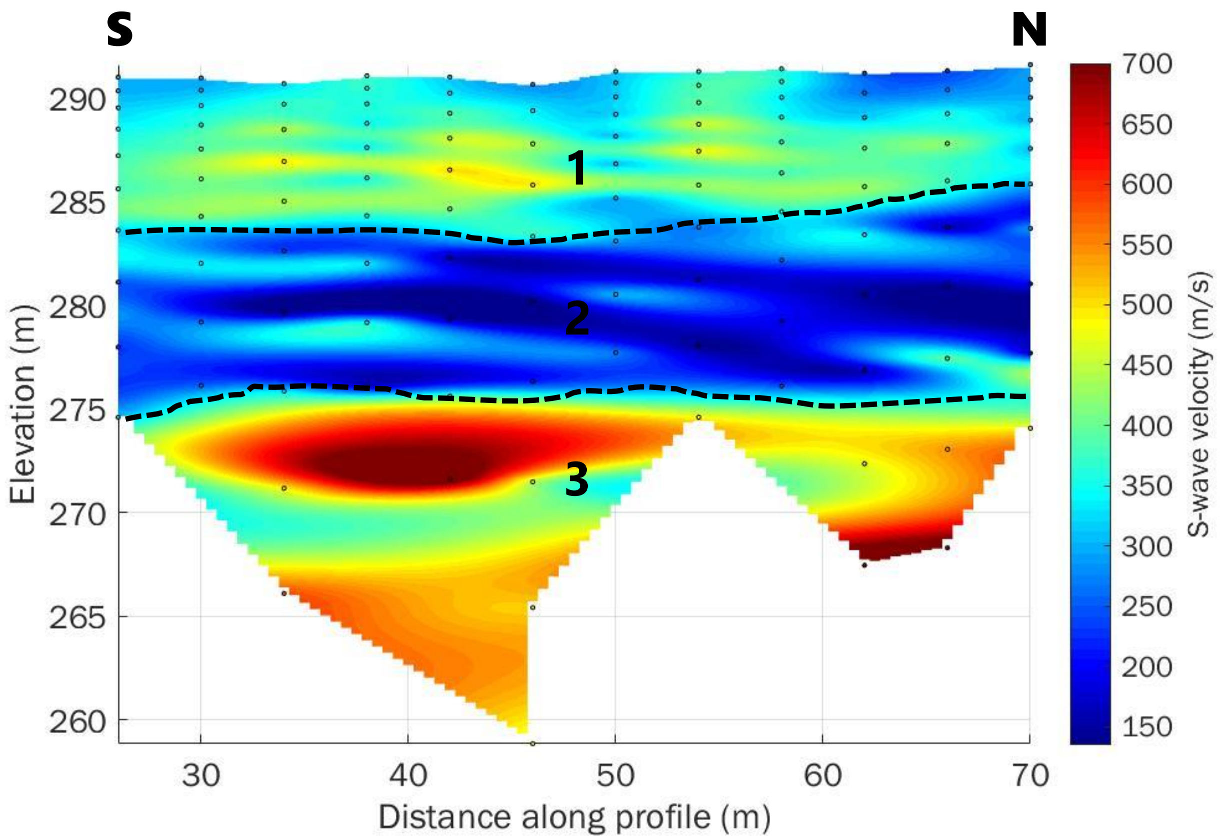
Objectives :

- Characterization of the shear wave velocity structure of the subsurface indicating layers of different waste composition and the transition to the host material

Measurements :

- One profile deployed between the geoelectric profiles on a smooth topography zone
- Fixed receiver array of 48 vertical geophones (4.5 Hz natural frequency) at 2 m intervals
- Source moved every two geophones (4 m) from one extreme of the profile to the other
- A total of 20 shots was stacked at each shot point

MASW 2D SHEAR WAVE VELOCITY MODEL



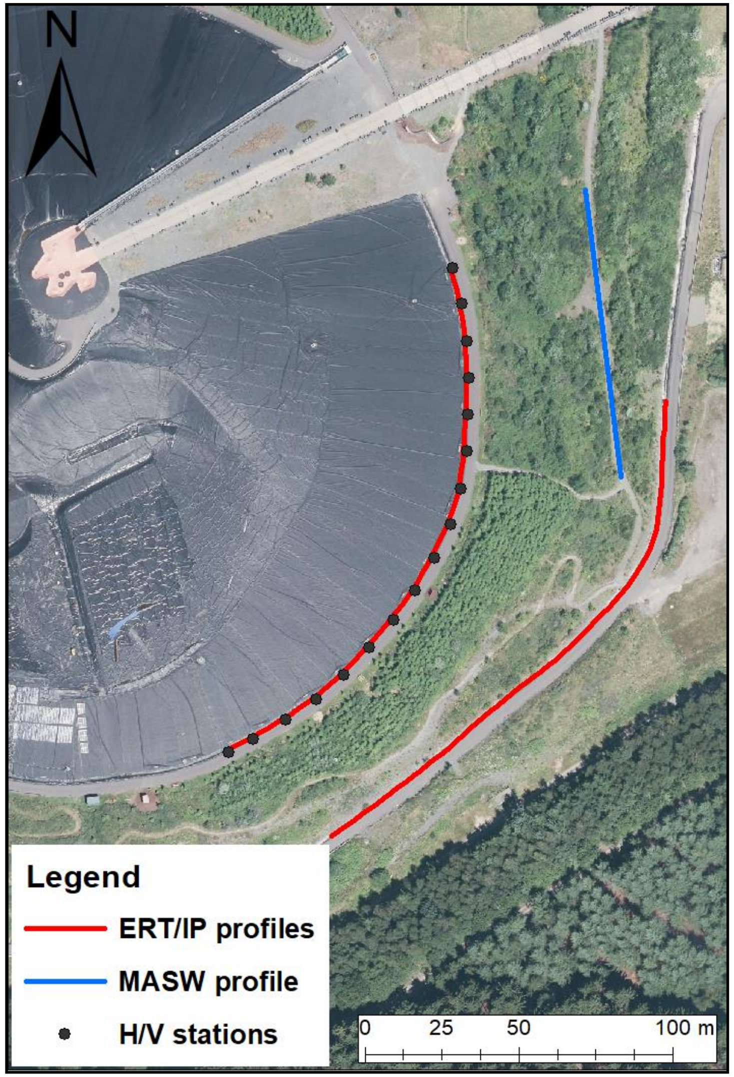
❑ **Three main heterogeneous layers:**

1. Characterized with intermediate velocities between 400 and 500 m/s; Might be related to the topmost ash layer

2. A thicker layer of low velocities from 150 m/s up to approximately 350 m/s; Might correspond to the intermediate household waste

3. In the bottom part (275 m elevation), increase in velocities up to 700 m/s; Might represent the natural soil beneath the waste deposits (in accordance with old topographic maps)

HVNSR



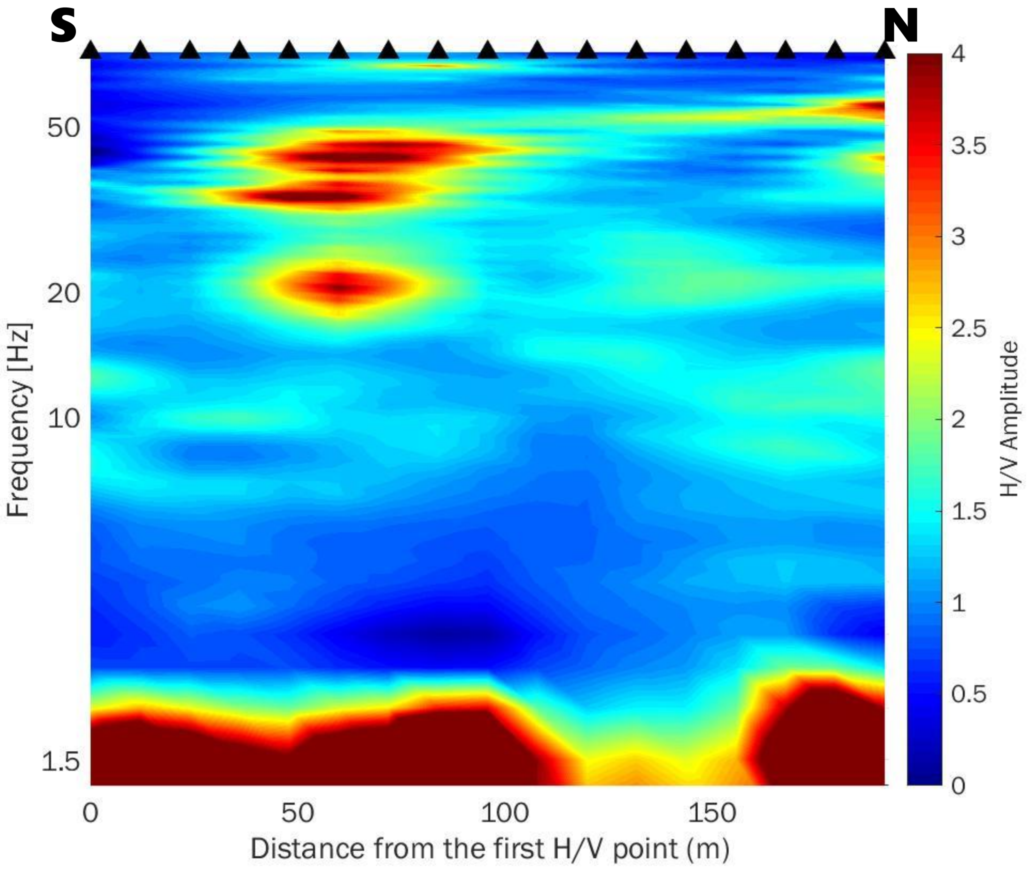
❑ **Objectives :**

- Estimation of the thickness of the waste and/or different material deposits depending on the mechanical contrast with the underlying media

❑ **Measurements :**

- Acquisition with a three-component sensor with a low cut-off frequency of 1 Hz (seismometer *LE-3Dlite MkIII Lennartz*)
- Ambient noise recorded at 17 locations along the upper ERT/IP profile
- Spacing of 12 m between each station
- Recording time set to 20 minutes

HVNSR 2D fundamental peaks profil



- Interpolation of the H/V amplitude along the position of all the stations to visualize the fundamental peak(s) and their continuity along all the stations
- For almost all stations, one fundamental peak centred around 1.5 Hz; Might be associated with a layer at a larger depth
- Between station 4 to 8 and the last one, other contributions are also observed at frequencies around 20-50 Hz; Might be associated with a layer at a shallower depth

HVNSR THICKNESS ESTIMATION

- Transformation of the frequencies linked to two fundamental peaks - $f_{\beta 1}$ and $f_{\beta 2}$ - to roughly determine h_1 and h_2 thicknesses along the H/V profile
- Use of the shear velocities estimated during the MASW (β_1 and β_2) and the formulas (Piña-Flores et al., 2017) :

$$f_{\beta 1} = \frac{\beta_1}{4h_1} \qquad f_{\beta 2} = \frac{1}{4\left(\frac{h_1}{\beta_1} + \frac{h_2}{\beta_2}\right)}$$

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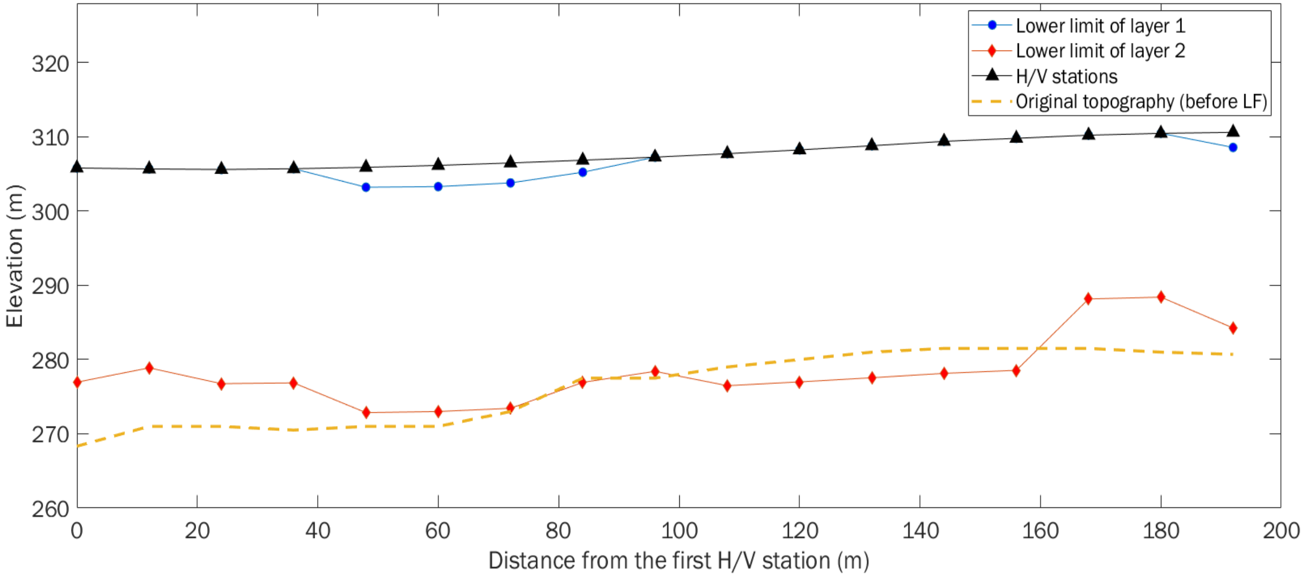

- The estimated bottom limit fits the original topography before the MSW disposal
- A shallowest layer only present for the intermediate and last stations, as the associated fundamental peak was not continuous

Conclusion

- **ERT/IP :**

✓ Delineation of inert waste from household/ash deposits

✗ Not sensitive enough to individually identify and locate these materials with certainty

✓ The IP method remains more promising for the estimation of waste types and volumes in zones with good coverage

- **MASW :**

✓ Detection of three distinctive layers (ash, MSW, geological host)

- **HVNSR :**

✓ Estimation of the bottom layer in good agreement with the topography known before landfilling

REFERENCES

- Dahlin, Torleif, and Bing Zhou. 2006. 'Multiple-gradient array measurements for multichannel 2D resistivity imaging', *Near Surface Geophysics*, 4: 113-23.7

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