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SUMMARY

Contaminants in leachate plumes from landfills and other contaminated sites are a threat to the environment. Efficient site characterization methods are needed. The perspectives of the IP method are investigated in combination with geological sampling and chemical analyses of water samples. Along a leachate plume from a landfill hosting both household and chemical waste, borehole IP data, geological samples, grain size, and contaminant concentrations in water samples are examined for correlations related to geology and concentrations of contaminants.

Results relating the Cole-Cole parameters with sediment types and pore water resistivity representing the concentrations of the contaminants show that the formation resistivity primarily is controlled by the contaminant concentrations while the IP parameters primarily are related to the clay content and grain size distribution of sandy sediments at the site.

Key words: Cole-Cole parameters, clay content, grainsize analyses, landfill leachate plume.

INTRODUCTION

Leachate plumes from landfills and other contaminated sites are a threat for groundwater, surface water, and eco systems. Efficient mapping and site characterization are required for the establishment of reliable monitoring and remediation plans.

The GEOCON project aims at advancing geological, geophysical and contaminant monitoring technologies for contaminated site investigations. The induced polarization method (e.g., Revil et al. 2012) both applied at the surface and in boreholes is brought into an integrated site characterization scheme with water sampling, geological and hydrogeological site models and coupled transport models. One of the research questions that have to be addressed is whether it is possible to separate the IP response from the contaminants from the ones from the geology. To answer this question we examine borehole IP data, geological samples, grain size, and contaminant concentrations in water samples along a leachate plume from a landfill hosting both household and industrial chemical waste using various statistical tools. Preliminary results are presented here.

METHOD AND RESULTS

The field site and the geological setting

The field site, Grindsted Landfill is situated in the south-western part of Jutland, Denmark. The landfill has been active for about 50 years from the 1930'ies to the 1970'ies, where household waste and construction material have been deposited along with chemical waste from a local chemical industry (Kjeldsen et al. 1998).

In the area thin layers of quaternary deposits cover Miocene deposits. The quaternary sediments mainly consists of coarse sandy meltwater deposits while the Miocene sediments primarily are medium to fine mica-rich sand and interbedded thin clay and lignite layers deposited in a flood plain or coastal lagoon environment.

The landfill, its leachate plume and the surrounding areas have earlier been subject to a high number of mainly chemical investigations of water samples from boreholes (e.g, Kjeldsen et al 1998).

Field methods and data

Three El-log drillings (Sørensen 1989) are carried out at the leachate plume in front of the Grindsted Landfill. The El-log method is expanded to measure time-domain IP along with the electrical resistivity in a 20 cm normal configuration and gamma radiation (Auken et al, 2016). The geophysical data are acquired in-situ while auger drilling. The DCIP data are inverted for the Cole-Cole parameters using a 1D vertical constrained inversion procedure (Fiandaca et al. 2012).

Since no useful geological samples are obtained by the El-log auger drilling, an additional borehole is drilled one metre a part from one of the El-log positions to achieve high quality geological samples. All samples are geologically described and selected samples are analysed for the grain-size distribution.

All boreholes are screened at different levels for water sampling. Additionally the El-log method collects water samples.

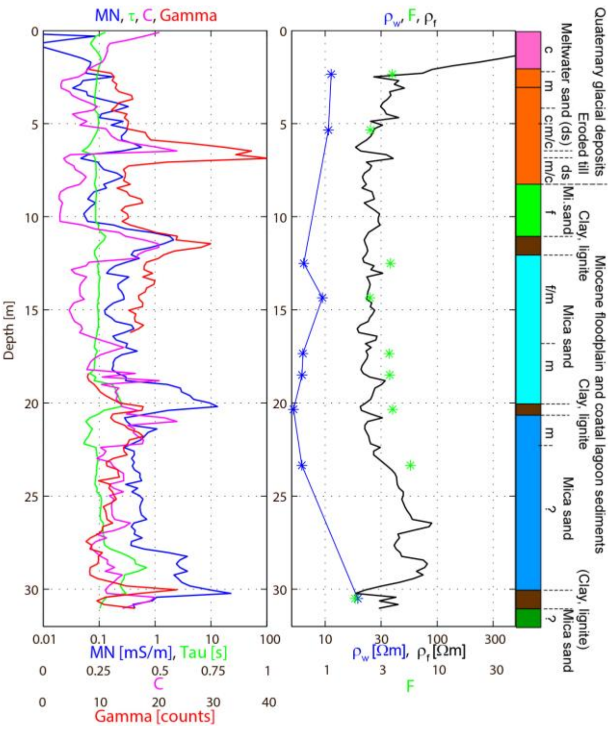

Figure 1. Geophysical borehole logs (Gamma, The Cole-Cole parameters: formation resistivity ρ_f, normalized chargeability MN, relaxation time τ, constant controlling the frequency dependence C), pore water resistivity (ρ_w), formation factor (F) and lithological log at borehole B1. The right-hand side colour-coded column indicate the geological log as observed in samples in the interval 0-22 m depth and interpreted from gamma log in the interval 22-32 m. The geological determined grain size of the sandy sediments are marked (f=fine, m=medium, c=coarse).

The logging results

The DCIP data from borehole B1 presented as Cole-Cole parameters are shown in Figure 1, together with the Gamma-log, the pore water resistivity measured on water samples at nine levels. At these nine levels the formation factor is calculated. The geological log from borehole B2, one metre a part from borehole B1, is supplemented with deposition environment, the sediment type and the geological determined grain size of the sandy sediments (Figure 1).

Correlations

The overall trend of the formation resistivity log measured by the El-log and the pore water resistivity measured on water samples are similar (Figure 1). The concentration of some of the contaminants controls the pore water resistivity and thereby the formation resistivity, at least in the clay-free parts of the ground. In other boreholes at the site, the non-contaminated pore water above the leachate plume is observed to have resistivities above 100 Ωm.

From a visual inspection of the DCIP log and the geological log it can be seen that the highest levels in the normalized chargeability above 1 mS/m are related to the clay and lignite layers (Figure 1). Cross plots of the Cole-Cole parameters colour-coded with the related geological description or interpretation display clear coherence between the Cole-Cole parameters and the sediment type (Figure 2). Different types of relationships are indicated in the cross plots for combinations of Cole-Cole parameters and sediment types related to clay content and grain size of the sandy sediments.

Taking all data into account there is no significant evidence of that the contaminants in the leachate plume at Grindsted Landfill influence on the IP response.

CONCLUSIONS

We examine borehole IP data, geological samples, grain size, and contaminant concentrations in water samples along a leachate plume from a landfill hosting both household and industrial chemical waste using various statistical tools with the purpose of addressing the question whether it is possible to separate the IP response from the contaminants from the ones from the geology.

In the primarily sandy sediments at the Grindsted Landfill we have observed (1) that the formation resistivity overall correlate with the pore water resistivity, representing concentrations of some of the contaminants, (2) that the IP parameters MN, τ and C seems to correlate with clay content and grain size of the sandy sediments and (3) that there is no significant evidence of that the contaminants influence on the IP parameters MN, τ and C.

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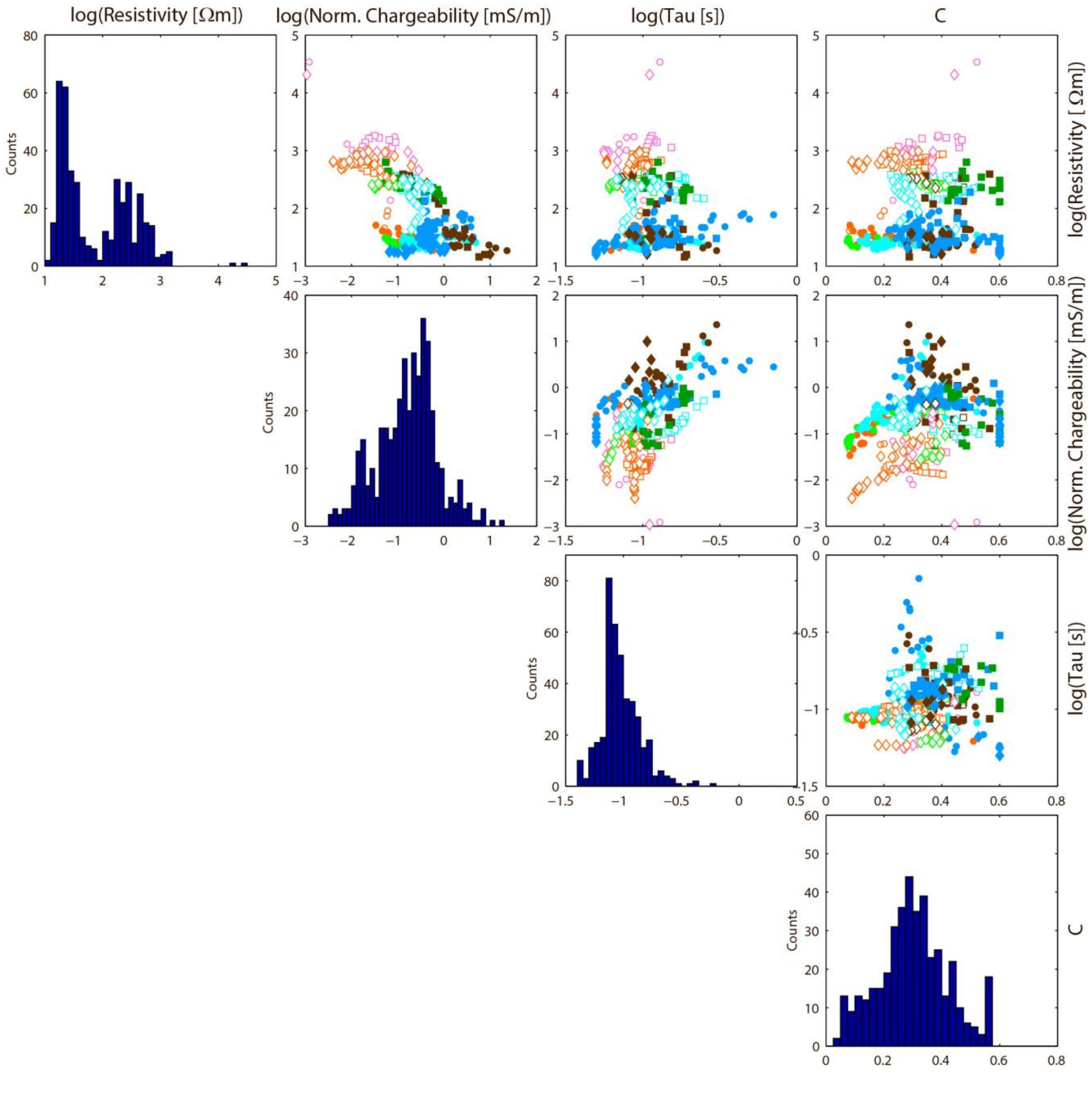

Figure 2. Histograms and cross plot of the Cole-Cole parameters from the three El-log drillings. The parameters are colour coded according to the geological log in Figure 1. An open plotting symbol indicates no or weak concentrations of contaminants, while a filled plotting symbol indicates high concentrations of contaminants. Data from B1, B3 and B5 are marked with a circle, square and a diamond, respectively.